U.S. Fish and Wildlife Service
Maine Field Office
Special Project Report: FY00-MEFO-1-EC

Trace Element Exposure in Benthic Invertebrates from Grove Pond, Plow Shop Pond, and Nonacoicus Brook

Ayer, Massachusetts

September 2000

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Ayer, Massachusetts

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EXECUTIVE SUMMARY

Remedial investigations associated with the Superfund Program of the U.S. Environmental Protection Agency (EPA) found highly elevated levels of several trace elements in sediment samples from Grove Pond and Plow Shop Pond in Ayer, Massachusetts. Due to the nature and extent of contamination, federal and Massachusetts regulatory and natural resource management agencies were concerned that arsenic, cadmium, chromium, mercury, lead and other trace elements may be accumulating in the benthic community of the ponds or being transported downstream to Nonacoicus Brook and the Nashua River. The U.S. Fish and Wildlife Service was asked by EPA to conduct a limited, screening-level contaminant study of two benthic organisms inhabiting the ponds and brook.

The purposes of the study were:

< To determine arsenic, cadmium, chromium, mercury, and lead exposure in mussels and crayfish, and

< To provide the U.S. Environmental Protection Agency and Massachusetts Department of Environmental Protection with site-specific data for human health and ecological risk assessments of Grove Pond and Plow Shop Pond.

In July and September 1998, the USFWS collected 12 composite tissue samples of mussels (*Elliptio complanata*) and 4 wholebody composite samples of crayfish (*Orconectes* spp.). Mussel were collected from 2 locations in Plow Shop Pond (alongside the culvert from Grove Pond and above the dam) and 2 locations in Nonacoicus Brook (below the Plow Shop Pond dam and near the confluence with the Nashua River). Crayfish composite samples were collected in Grove Pond (below the Barnum Road gate) and in Plow Shop Pond (alongside the culvert from Grove Pond). The samples were analyzed at the Research Triangle Institute (a contract laboratory of the USFWS Patuxent Analytical Control Facility) for 19 trace elements and methyl mercury. Levels of metals in tissues of mussels and crayfish collected from the ponds and brook were compared by sampling location and also compared to concentrations reported in the scientific literature. The results of these comparisons are summarized below:

<u>Mussels</u>

Arsenic, cadmium, chromium, and mercury were detected in all mussel tissue samples (n=12). Lead was detected in only 9 samples. Arsenic concentrations appeared higher in samples from Nonacoicus Brook than in Plow Shop Pond. Concentrations of cadmium, chromium, mercury and lead were similar in 3 of 4 locations. The collection location in Nonacoicus Brook near the confluence of the Nashua River, however, was dissimilar than the other 3 locations and exhibited higher levels of cadmium, chromium, mercury, and lead.

Mussels from Plow Shop Pond and Nonacoicus Brook did not have highly elevated concentrations of arsenic, cadmium, mercury, methyl mercury or lead in their tissues as compared to findings reported elsewhere. However, chromium levels in mussel composite samples collected near the terminus of Nonacoicus Brook (100 meters before the confluence with the Nashua River) were elevated (5.07 ppm).

Crayfish

Arsenic concentrations in wholebody crayfish from the two ponds were similar and comparable to levels reported in other studies. Cadmium, chromium, and lead were lower in the composite sample from Plow Shop Pond than the mean concentration of composite samples from Grove Pond. In contrast, mercury levels appeared higher in the Plow Shop Pond sample (0.05 ppm) than in the Grove Pond samples (mean 0.03 ppm). Cadmium, chromium, and lead levels in composite samples from Grove Pond were highly variable. Concentrations of these metals in the Grove Pond composite samples differed by factors of 2 (Pb, Cr) or 3 (Cd).

The levels of arsenic, cadmium, mercury and lead in crayfish do not appear to be highly elevated compared to studies reported in the scientific literature. Insufficient information was obtained in the literature review, however, to determine if the chromium levels in crayfish from Grove Pond (mean 0.85 ppm) and Plow Shop Pond (0.48 ppm) are elevated.

PREFACE

This report includes the analytical results of a limited, screening-level survey of trace elements in benthic invertebrates (mussels and crayfish) from Grove Pond, Plow Shop Pond, and Nonacoicus Brook in Ayer, Massachusetts. Funding for this study was provided by Region 1 of the U.S. Environmental Protection Agency (EPA) under interagency agreements between the U.S. Fish and Wildlife Service (USFWS) and EPA for technical assistance in the Superfund Program (EPA/IAG No. DW14934248-01-F and No. DW14938094-01-0). The USFWS analytical catalog number for this project was 5030086 and the purchase order number was 92223-99-Y363.

Questions, comments, and suggestions related to this report are encouraged. Written inquiries should refer to Report Number FY00-MEFO-1-EC and be directed to:

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Road, Research Triangle Park, NC. Purchase Order 92223-99-Y363. USFWS Patuxent Analytical Control Facility Catalog Number 5030086. 24 pages.

1. INTRODUCTION

Grove Pond and Plow Shop Pond form the northeastern border of the former Fort Devens Military Reservation in Ayer, Massachusetts. The two ponds essentially comprise one aquatic community, separated by a railroad right-of-way and connected by a large, stone culvert bridge. Fish can easily move between ponds through the culvert. Waterfowl and wading birds are often observed foraging on both ponds and flying over the railroad right-of-way from one pond to the other. The ponds drain into Nonacoicus Brook, which empties into the Nashua River. Remedial investigations associated with EPA's Superfund Program found highly elevated levels of several trace elements (As, Cd, Cr, Hg, Pb) in sediment samples from Grove Pond and Plow Shop Pond (ABB 1995). In Plow Shop Pond, the maximum sediment concentrations of arsenic (2,700 : g/g, dry weight (dw)), cadmium (16 : g/g, dw), chromium (8,800 : g/g, dw), mercury (250 : g/g, dw), and lead (1,000 : g/g, dw) are well above freshwater sediment effect levels and sediment quality guidelines (Ingersoll *et al*. 1996, MacDonald *et al*. 2000). The maximum mercury concentration in Grove Pond sediments (220 : g/g, dw) is also highly elevated. Studies by Army contractors (ABB 1993) and the USFWS (Mierzykowski *et al*. 1993) conducted on Plow Shop Pond and Grove Pond, respectively, also showed metal uptake in fish (Table 1). Largemouth bass from Plow Shop Pond contained highly elevated concentrations of mercury (max. 2.70 : g/g, wet weight) in their tissue.

Due to the nature and extent of contamination, federal and Massachusetts regulatory and resource agencies were concerned that mercury and other trace elements may be accumulating in the benthic invertebrate community of the ponds or being transported downstream to Nonacoicus Brook and the Nashua River. USFWS was asked by EPA to conduct a limited, screening-level contaminant study of two benthic organisms inhabiting the ponds and brook.

2. STUDY PURPOSES

The purposes of the study were:

< To determine arsenic, cadmium, chromium, mercury, and lead exposure in mussels and crayfish, and

< To provide the U.S. Environmental Protection Agency and Massachusetts Department of Environmental Protection with site-specific data for human health and ecological risk assessments of Grove Pond, Plow Shop Pond, and Nonacoicus Brook.

3. STUDY AREA

The study area included Grove Pond, Plow Shop Pond, and Nonacoicus Brook in the Town of Ayer, Middlesex County, Massachusetts. Ayer is located in central Massachusetts, approximately 56-km (35 mi) northwest of Boston.

3.1 Grove Pond - Grove Pond is a 28-ha (70 ac) shallow pond at coordinates 42º 33' N/71º 35' W. The pond is bordered by residential areas and a recreational park of the Town of Ayer to the north, woodlands associated with the former Fort Devens military reservation to the south and east. Railroad tracks and roadway to the west separate Grove Pond from Plow Shop Pond. A stone culvert connects the ponds. Drainages into Grove Pond include Cold Spring Brook, an unnamed stream near the Devenscrest residential area, and the outflow from Flannagan Pond.

Grove Pond is eutrophic with dense, abundant stands of aquatic vegetation. Floating and submerged aquatic vegetation are substantial and include duckweed (*Lemna minor*), yellow water lily (*Nuphar variegatum*), pickerelweed (*Pontederia cordata*), and coontail (*Ceratophyllum* spp.). Fish species in the pond are typical of warmwater communities - largemouth bass (*Micropterus salmoides*), chain pickerel (*Esox niger*), brown bullhead (*Ameiurus nebulosus*), bluegill (*Lepomis macrochirus*) and pumpkinseed (*L. gibbosus*). Great blue heron (*Ardea herodias*), Canada geese (*Branta canadensis*), mallards (*Anas platyrhnychos*), wood duck (*Aix sponsa*), belted kingfisher (*Ceryle alcyon*), and tree swallow (*Tachycineta bicolor*) are common bird species using Grove Pond. Representative reptiles and amphibians are the snapping turtle (*Chelydra serpentina*), eastern painted turtle (*Chrysemys picta*), northern water snake (*Nerodia sipedon*), bullfrog (*Rana catesbeiana*), green frog (*R. clamitans*), and pickerel frog (*R. palustris*). Muskrat (*Ondatra zibethica*) and raccoon (*Procyon lotor*) sign are frequently encountered along the shore. Bank dens of beaver (*Castor canadensis*) can also be found along the pond edge. During frog sampling in 1999, USFWS personnel watched a mink (*Mustela vison*) foraging along the western bank of the pond.

3.2 Plow Shop Pond - Plow Shop Pond is a 12-ha (29 ac) shallow water body at coordinates N42º 33' 20", W71º 35' 33". The pond is bordered by commercial businesses in the Town of Ayer to the north, grassland and woodland associated with the Shepley's Hill landfill to the west and south, and a roadway and railroad track system to the east. As an aquatic community, Plow Shop Pond is similar in many ways to Grove Pond. However, Plow Shop Pond is smaller and slightly deeper, and aquatic vegetation tends to be less dense than Grove Pond. Wildlife species using Plow Shop Pond are the same as Grove Pond. River otter (*Lutra canadensis*) have been infrequently observed in Plow Shop Pond near Nonacoicus Brook (T. Poole, US Army/Devens Natural Resources Branch, personal communication).

3.3 Nonacoicus Brook - Nonacoicus Brook is a 2.5-km (1.6 mi) long shallow stream that flows westerly from the Plow Shop Pond dam into the Nashua River. The brook could receive contaminants from other sources besides Plow Shop Pond and Grove Pond. Below the Plow Shop Pond dam, Nonacoicus Brook passes under a secondary roadway, a state highway, and a commuter railway. A small wetland north of Ayer's West Main Street, west of the railroad tracks and south of Brook Street, drains easterly into Nonacoicus Brook. Over the next 1.6-km (1 mi) the stream passes through woodlands, old fields, and powerline right-of-ways. Approximately 1.8-km (1.1 mi) downstream from the Plow Shop Pond dam, Willow Brook, a drainage of Robbins Pond, flows into Nonacoicus Brook.

Dense populations of freshwater mussels, primarily the eastern elliptio (*Elliptio complanata*) exist in the brook immediately below the Plow Shop Pond dam. In 1995, USFWS personnel found the shell of a State-listed mussel species, the triangle floater (*Alasmidonta undulata*), in Nonacoicus Brook below the dam.

4. METHODS

4.1 Collections

4.1.1 Collection Locations - Mussels were collected in Plow Shop Pond and Nonacoicus Brook on July 21 and 22, 1998. Crayfish were collected in Grove Pond and Plow Shop Pond between September 1-8, 1998. Mussels were collected in two Plow Shop Pond locations: beside the culvert emptying from Grove Pond (PLO-03) and above the dam (PLO-06). In Nonacoicus Brook, mussels were collected below the Plow Shop Pond dam (NON-07) and above McPherson Road (NON-10). Nonacoicus Brook enters the Nashua River approximately 90-m (300 ft) downgradient of NON-10. Insufficient numbers of mussels were found in Grove Pond for contaminant analysis, consequently no animals were collected.

In Grove Pond, crayfish were collected in the inlet pool below the Barnum Road bridge where Cold Spring Brook enters the pond. The Barnum Road Bridge location in Grove Pond is upgradient of contamination associated with the former tannery. In Plow Shop Pond, crayfish were captured along the western edge of the pond below the railroad tracks.

The mussel and crayfish collection locations are depicted in Figures 1 (mussels) and 2 (crayfish), and the coordinates listed in Table 2.

4.1.2 Mussels - Mussels were located with viewing buckets and collected by hand. *E. complanata* was the only mussel species observed and collected. Shell exteriors were scrubbed at the collection sites with ambient water. All mussels were measured. Mussel metrics recorded include length, width, breadth, total weight, and tissue weight (shucked sample). Shell length, width, and breadth were measured with dial calipers in millimeters. Total weight and tissue weight were measured to the nearest gram on a portable electronic balance (Tables 3 - 6). Five mussels of the same species and of similar size were composited sample. Three samples were collected at each location. Tissue composites were placed in chemical-clean glass jars with teflon lids, labeled, and frozen.

4.1.3 Crayfish - Crayfish (*Orconectes* spp.) were collected in modified cylindrical wire minnow traps baited with portions of sunfish (*Lepomis* spp.) captured at each trap site. Traps were checked every 24 hours, and, if necessary, rebaited. Upon capture, crayfish total length - from the tip of the rostrum to the end of the telson - was measured with dial calipers to the nearest millimeter. Total weight was determined to the nearest gram on a portable electronic balance (Table 7). Individual crayfish were placed in labeled plastic bags and frozen. Prior to shipping to the analytical laboratory, individual crayfish were combined into composites based on weight and capture location.

4.2 Analytical Methods

4.2.1 Metal Analyses - Composites of crayfish and freshwater mussels were sent to Research Triangle Institute, a contract laboratory of the USFWS Patuxent Analytical Control Facility (PACF). Samples were analyzed for a routine scan of trace elements (n=19), plus methyl mercury and percent moisture. Analytical methods and procedures for Graphite Furnace Atomic Absorption and Cold Vapor Atomic Absorption are described in pages 18-24 of the Appendix.

4.2.2 QA/QC - Quality assurance and quality control procedures of the PACF included analysis of procedural blanks, duplicates, certified reference material, and spike recoveries (Appendix, pages 10-16). No anomalies were found during QA/QC and the analytical results were accepted by PACF (Appendix, pg. 17). The ratio of methyl mercury to total mercury was exceeded in two crayfish composite samples (BAR-CY01, BAR-CY02). Methyl mercury analyses may exhibit variability of ± 20%, so a MeHg/Total Hg ratio > 1 is not highly unusual (T. Haines, USGS/BRD, personal communication).

4.2.3 Data Presentations - Contaminant concentrations presented in the text of this report and Tables 8 through 11 are presented in : g/g (ppm, parts-per-million), **wet weight**. Wet weight concentrations are presented because those units are often used in ecological and human health risk assessments - the principle users of the data in this report. Often in the scientific literature, however, contaminant levels in benthic organisms are presented on a dry weight basis. Although dry weight data are not used in the text of this report, Tables 12 through 15 list and summarize dry weight values for mussel and crayfish composites.

5. ANALYTICAL RESULTS

5.1 Metals of Concern (As, Cd, Cr, Hg, Pb) - The focus metals of this contaminant investigation were arsenic, cadmium, chromium, mercury (total mercury and methyl mercury), and lead. Tables 8 (mussels) and 9 (crayfish) list the analytical results for these five metals in wet weight. Tables 10 (mussels) and 11 (crayfish) present wet weight values for other metals detected in the inorganic scan. Complete listings of all results are provided in the Appendix.

5.1.1 Mussels - **Arsenic** concentrations in mussel tissue composites ranged from 0.66 : g/g to 1.17 : g/g[1], with higher levels occurring in samples collected from Nonacoicus Brook. **Cadmium** concentrations in mussels from Plow Shop Pond and at the beginning of Nonacoicus Brook below the pond dam were similar (range: 0.19 - 0.39 : g/g), but mussel composites collected at the end of the

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1 All tissue analytical results in the text are presented as wet weight concentrations.

brook had considerably higher Cd content (Θ 0.76 :g/g, range: 0.66 - 0.90 :g/g). Similarly, **chromium** levels were markedly higher in Nonacoicus Brook mussels collected near the confluence with the Nashua River (Θ 5.07 :g/g @ NON-10) than in the mussel composites collected further upstream below the Plow Shop Pond dam (0.59 :g/g @ NON-07) or in Plow Shop Pond (Θ 0.68 :g/g @ PLO-03; Θ 0.57 :g/g @ PLO-06). **Total mercury** levels ranged from 0.04 :g/g to 0.13 :g/g. The total Hg level in composites collected from Nonacoicus Brook near the confluence with the Nashua River were twice as high as levels in composites collected from other locations. **Methyl mercury** (MeHg) concentrations showed a similar pattern with the highest levels occurring in the Nonacoicus Brook samples collected near the Nashua River. Ratios of MeHg to Total Hg in mussel composites ran from 0.19 to 0.51. **Lead** concentrations in mussel composites exhibited the same pattern as Cd, Cr, and Hg, with the highest levels occurring in samples collected at NON-10 (Θ 1.10 :g/g).

5.1.2 Crayfish - Mean **arsenic** level in 3 composite samples of wholebody crayfish from Grove Pond was 1.41 :g/g. In the Plow Shop Pond composite crayfish sample, the As concentration was 1.62 :g/g. **Cadmium** concentrations in 4 samples from the 2 ponds ranged widely from 0.11 :g/g to 1.07 :g/g, with the greatest concentrations occurring in the samples from Grove Pond. Similarly the composite crayfish samples from Grove Pond had higher levels of **chromium** (Θ 0.85 :g/g, range: 0.56 - 1.19 :g/g) and **lead** (Θ 0.67 :g/g, range: 0.45 - 0.89 :g/g) than the Plow Shop Pond sample (Cr 0.48 :g/g, Pb 0.28 :g/g). In contrast, the **total mercury** and **methyl mercury** levels in the Plow Shop Pond composite sample were twice as high as the mean Hg and MeHg levels for the Grove Pond composite samples. Ratios of MeHg to Total Hg in crayfish composites ranged from 0.74 to 1.22.

5.2 Other Metals - In addition to the 5 metals listed above, concentrations of 14 other trace elements were measured. In mussel composites, concentration ranges of these other metals were: aluminum (nondetect - 40.40 :g/g), boron (nondetect - 0.47 :g/g), barium (32.0 :g/g - 95.1 :g/g), copper (0.57 :g/g - 1.50 :g/g), iron (503 :g/g - 1,372 :g/g), magnesium (81.1 :g/g - 130.0 :g/g), manganese (581 :g/g - 1,079 :g/g), nickel (nondetect - 0.21 :g/g), selenium (0.15 :g/g - 0.31 :g/g), strontium (12.0 :g/g - 26.2 :g/g), and zinc (14.6 :g/g - 24.6 :g/g). Molybdenum was detected in only two of 12 mussel composite samples - 0.17 :g/g in NON-10B and 0.10 :g/g in NON-10C. Beryllium and vanadium were not detected in mussel tissue.

In crayfish composite samples collected below the Barnum Gate bridge in Grove Pond, the mean concentrations of these other metals were: aluminum 26.73 :g/g, barium 30.5 :g/g, copper 18.97 :g/g, iron 260.0 :g/g, magnesium 396.0 :g/g, manganese 719.3 :g/g, nickel 1.26 :g/g, strontium 140.3 :g/g, and zinc 28.4 :g/g. In the single, composite crayfish sample collected at the Plow Shop Pond culvert, the concentrations of non-target metals were: aluminum 2.94 :g/g, barium 37.7 :g/g, copper 24.40 :g/g, iron 349 :g/g, magnesium 388 :g/g, manganese 278 :g/g, nickel 0.27 :g/g, strontium 157 :g/g, and zinc 23.3 :g/g.

Molybdenum was detected in only one crayfish composite sample, BAR-CY03 collected below the

Barnum Gate bridge, at a level of 0.86 : g/g. Boron, beryllium, vanadium, and selenium were not detected in any crayfish tissue samples.

5.3 Percent Moisture - Percent moisture in 12 composite mussel samples ranged from 82.0% to 87.3%. In 4 composite crayfish samples, the moisture content was 72.9%, 69.3%, 68.0%, and 70.4%.

6. DISCUSSION

The discussion section is limited to the 5 trace elements (As, Cd, Cr, Hg, Pb) potentially related to historical tannery operations at Grove Pond or landfill activities near Plow Shop Pond.

Contaminant concentrations in mussels and crayfish from studies reported in the scientific literature are used for comparative purposes and to illustrate "background" values. If available, trace elements levels in mussel and crayfish studies from contaminated areas are also presented. **Contaminant concentrations reported on a dry weight basis in any of these sources were converted to wet weight based on moisture contents of 80% (mussels) or 70% (crayfish) using the formula: conc. WW = (conc. DW)(1-(% moisture/100)).** The values reported in these various studies include different species and sizes of mussels and crayfish, and animals collected from sites with varying degrees of contamination. These different data sets are presented only for qualitative comparisons.

6.1 Mussels. Mussels often comprise a large percentage of the total biomass of the aquatic benthic community (Naimo 1995). Mussels are remarkably long-lived organisms. The eastern elliptio (*Elliptio complanata*) may live over 60 years (S. von Oettingen, USFWS, personal communication), while pearl mussels (*Margaritifera margaritifera*) may live over 100 years (Bauer 1992). Freshwater mussel have limited home ranges and are sedentary. In one week, tagged *E. complanata* in a Quebec study moved an average of 12 cm in mid-summer (Amyot and Downing 1997). In a study of *E. complanata* in Virginia, tagged mussels moved an average of 2.9 m during one year (Balfour and Smock 1995).

Mussels are a forage species for many ecological receptors. Glochidia (mussel larvae) and juvenile mussels are prey of fish, birds, and mammals (Martin 1997). Adult mussels are consumed by muskrat, mink, otter, raccoon, and some birds (Toweill and Tabor 1982, Grubb and Coffey 1982, Cummings and Mayer 1992, Strayer and Jirka 1997). Middens, piles of empty mussel shells, along the banks of ponds or streams are a typical sign of muskrat, otter, or raccoon foraging. These middens of empty shells can be used to determine mussel species inhabiting a watercourse or waterbody (Cummings and Mayer 1992).

Mussels are commonly used in contaminant investigations. As filter-feeders and benthic dwellers, they are exposed to contaminants in the water column and sediment (Tessier *et al.* 1984, Naimo 1995). Sedentary, long-lived freshwater mussels have two advantages as a monitoring organism - an inability to avoid a pollutant, and their exposure in a natural environment to a pollutant over a long period of time (Foster and Bates 1978).

6.1.1 Arsenic (As) in Mussels - Arsenic was detected in all mussel samples (n=12). The lowest As concentration (0.59 :g/g) was found in the composite sample collected in Plow Shop Pond alongside the culvert from Grove Pond (PLO-03). Mussel composite samples from the two locations on Nonacoicus Brook (NON-07, NON-10) and from the Plow Shop Pond dam (PLO-06) had mean As levels ranging from 0.85 :g/g to 1.10 :g/g.

Levels of As in mussels from Maine and Quebec were similar to the results above. *E. complanata* and *Anodonta implicata* (alewife floater) from the Dennys River, East Machias River, and Meddybemps Lake in Maine had As concentrations ranging from 0.52 :g/g to 0.99 :g/g (Mierzykowski *et al.* 1998). Mussels collected downstream of 3 metal-discharging industries on the St. Lawrence River in Quebec had mean As concentrations of 0.68 :g/g[2] (range: 0.42 - 0.90 :g/g) in *E. complanata* and 1.09 :g/g (range: 0.54 - 2.08 :g/g) in *Lampsilis radiata* (Metcalf-Smith *et al.* 1996). In a broader mussel survey of 11 sites of differing pollution status on the St. Lawrence River (Metcalf-Smith *et al.* 1996), the As ranges in *E. complanata* and *L. radiata* were 0.56 - 1.5 :g/g and 0.84 - 1.72 :g/g, respectively. The lowest As levels we found in the literature were reported by Heit *et al.* (1980) in New York, who found a mean As concentration in *E. complanata* of 0.06 :g/g.

Compared to the Maine and Quebec data, As levels in Plow Shop Pond and Nonacoicus Brook mussels do not appear elevated. Compared to New York results, however, the As levels in the brook and pond could be considered elevated.

6.1.2 Cadmium (Cd) in Mussels - Cadmium was detected in all mussel composite samples. The mussel composite sample collected in Nonacoicus Brook near the confluence with the Nashua River (NON-10) had a mean Cd concentration (0.76 :g/g) twice as high as the composite samples from other locations in the brook and Plow Shop Pond (range: 0.24 - 0.32 :g/g).

Several papers were located listing Cd levels in mussels. Anderson (1977) reported Cd concentrations ranging from 0.06 :g/g to 1.17 :g/g in *Lampsilis siliquoidea*, *L. ventricosa*, *Strophitis rugosus*, and *Sphaerium*. Mean Cd in *Anodonta anatina* from the River Thames was 0.68 :g/g (Manly and George 1977). *E. complanata* and *Anodonta implicata* from two rivers and a lake in Maine had Cd concentrations ranging from 0.27 :g/g to 0.72 :g/g (Mierzykowski *et al.* 1998). *Amblema plicata* and *Plectomerus dombeyanus* from 8 locations on the Big Sunflower River in Mississippi had mean Cd concentrations ranging from 0.07 :g/g to 0.12 :g/g (Tatem *et al.* 1994). *E. complanata* collected from 21 small lakes in south-central Ontario had concentrations ranging from 0.10 :g Cd/g to 1.5 :g Cd/g (Campbell and Evans 1991). Heit *et al.* (1980) reported a mean Cd concentration of

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[2] If necessary, dry weight mussel tissue data were converted to wet weight based on 80% moisture.

1.80 : g/g in *E. complanata* from New York.

Three studies reported Cd levels in uncontaminated and contaminated areas. In threeridge mussels (*Amblema plicata*), Naimo *et al.* (1992) reported Cd levels from a lightly contaminated site ranging from 0.11 : g/g to 0.18 : g/g and a range of 0.16 : g/g to 0.25 : g/g at a site influenced by industrial and domestic inputs. The Cd concentration in pocketbook mussels (*Lampsilis ventricosa*) prior to transplant below mining sites was 0.08 : g/g (Czarnezki 1987). After a 12-week exposure below the mining sites, the concentration increased to 2.26 : g/g.

Mussels collected downstream of 3 metal-discharging industries on the St. Lawrence River had mean Cd concentrations of 0.08 : g/g (range: 0.02 - 0.22 : g/g) in *E. complanata* and 0.10 : g/g (range: 0.04 - 0.32 : g/g) in *Lampsilis radiata* (Metcalf-Smith *et al.* 1996). In a broader survey of 11 sites of differing pollution status on the St. Lawrence River, Metcalf-Smith *et al.* (1996) found Cd in even higher ranges in *E. complanata* and *L. radiata* of 0.08 - 1.42 : g/g and 0.12 - 1.66 : g/g, respectively.

Qualitative comparisons of the Plow Shop Pond and Nonacoicus Brook mussel data to the levels reported in these other studies indicate that Cd levels from the brook and pond are not unusual or highly elevated.

6.1.3 Chromium (Cr) in Mussels - The highest mean Cr concentration (5.07 : g/g) was found in the mussel composite sample collected at the terminus of Nonacoicus Brook near the confluence with the Nashua River (NON-10). This location had Cr levels well above the concentrations in composites from other locations in the brook and pond (range: 0.57 : g/g - 0.68 : g/g).

Chromium residues in freshwater invertebrates from uncontaminated areas are generally #1 : g/g (Moore and Ramamoorthy 1984). In a New York study, the mean Cr concentration in *E. complanata* was 0.60 : g/g (Heit *et al.* 1980). In Maine, Mierzykowski *et al.* (1998) found Cr concentrations in *E. complanata* and *Anodonta implicata* tissue ranging from 0.24 : g/g to 0.62 : g/g. Freshwater mussels from 8 locations on the Big Sunflower River in Mississippi had mean Cr concentrations ranging from non-detect to 0.59 : g/g (Tatem *et al.* 1994).

Invertebrates from Cr-contaminated areas may contain as much as 5 : g/g (Moore and Ramamoorthy 1984). Mussels collected downstream of 3 metal-discharging industries on the St. Lawrence River had mean Cr concentrations of 5.16 : g/g (range: 1.62 - 9.18 : g/g) in *E. complanata* and 2.44 : g/g (range: 0.40 - 12.0 : g/g) in *Lampsilis radiata* (Metcalf-Smith *et al.* 1996). In a broader mussel survey of 11 sites of differing pollution status on the St. Lawrence River (Metcalf-Smith *et al.* 1996), the Cr ranges in *E. complanata* and *L. radiata* were 0.66 - 3.76 : g/g and 0.40 - 2.52 : g/g, respectively.

The levels of Cr in mussel tissue from Plow Shop Pond (PLO-03, PLO-06) and in Nonacoicus Brook below the dam (NON-07) do not appear elevated. Compared to upstream sampling locations and other studies, the levels of Cr in the mussel samples collected from location NON-10 (the outflow of the brook to the Nashua River) were elevated and consistent with data from Cr-contaminated sites reported in the scientific literature (Moore and Ramamoorthy 1984, Metcalf-Smith *et al.* 1996). The source of Cr in the lower portion of Nonacoicus Brook is unknown. Backwash of sediments from the Nashua River into Nonacoicus Brook is a possible source of chromium found in mussel tissue. In a fish study of the Nashua River upriver of Nonacoicus Brook, Mierzykowski *et al.* (1997) found highly elevated levels of Cr in wholebody yellow perch ($\bar{x}$ 13.51 μg/g; range: 0.89 - 44.63 μg/g). The Cr levels in perch from the Nashua River were similarly elevated compared to region-wide fish tissue concentrations examined by Yeardley *et al.* (1998).

6.1.4 Total Mercury (Hg) and Methyl Mercury (MeHg) in Mussels

Total mercury - Total mercury concentrations in mussel composite samples ranged from 0.04 μg/g to 0.13 μg/g. In 3 locations, total Hg levels were comparable (0.06 μg/g, 0.05 μg/g, 0.04 μg/g), but the Nonacoicus Brook location near the Nashua River (NON-10) had a higher total Hg concentration of 0.13 μg/g.

Several mussel/Hg studies have been conducted over the years. In a Minnesota study, Naimo *et al.* (1992) found Hg levels as high as 0.38 μg/g ($\bar{x}$ 0.12 μg/g) in *Amblema plicata*, while Malley *et al.* (1996) reported a composite wholebody concentration of 0.09 μg Hg/g in giant floater *Pyganodon grandis* from northwestern Ontario. Heit *et al.* (1980) reported a mean Hg concentration of 0.08 μg/g in *E. complanata* collected in Lake George, New York. In Maine, Hg concentrations in *E. complanata* and *Anodonta implicata* ranged from nondetect to 0.10 μg/g (Mierzykowski *et al.*1998). Freshwater mussels from 8 locations on the Big Sunflower River in Mississippi had mean Hg concentrations ranging from 0.01 μg/g to 0.02 μg/g (Tatem *et al.* 1994). Mean Hg in *Anodonta anatina* in the River Thames was 0.81 μg/g (Manly and George 1977).

Three studies of Hg and mussels from the Sudbury River watershed in Massachusetts were conducted in 1994 and 1995. In a USFWS survey (unpublished data), Hg concentrations in 33 *E. complanata* samples ranged from 0.03 μg/g to 0.23 μg/g with a mean of 0.09 μg/g. The initial concentration of total Hg in *E. complanata* used by Beckvar *et al.* (2000) in their *in-situ* transplant study was 0.13 μg/g. After a 12-week deployment below the Hg-contaminated site on the Sudbury River, mussels had a total Hg concentration of 0.19 μg/g. In one other Sudbury River mussel study, *E. complanata* collected below the Hg-contaminated site had total Hg concentrations ranging from 0.05 μg/g to 0.09 μg/g (Bock *et al.* 2000).

In a study of mussels collected downstream of 3 metal-discharging industries on the St. Lawrence River, the mean Hg concentration was 0.02 μg/g (range: 0.01 - 0.06 μg/g) in *E. complanata* and 0.02 μg/g (range: 0.01 - 0.06 μg/g) in *Lampsilis radiata* (Metcalf-Smith *et al.* 1996). In a broader mussel survey of 11 sites of differing pollution status on the St. Lawrence River (Metcalf-Smith *et al.* 1996), the Hg ranges in *E. complanata* and *L. radiata* were 0.01 - 0.07 : g/g and 0.01 - 0.03 : g/g, respectively.

The mean Hg levels in mussel tissue in Plow Shop Pond and Nonacoicus Brook are not unusual or highly elevated compared to regional and other mussel data.

<u>Methyl mercury</u> - Methyl mercury (MeHg), the organic and highly toxic form of mercury, was also included in the analysis of Plow Shop Pond and Nonacoicus Brook mussel tissue. Similar to the finding for total Hg, the highest levels of MeHg were detected in composite mussel samples collected from the terminus of Nonacoicus Brook (NON-10 with 0.043 : g/g).

The Plow Shop Pond and Nonacoicus Brook MeHg values were compared to 3 studies of *E. complanata* collected from the Sudbury River watershed in Massachusetts between 1994 and 1995 (USFWS, unpublished data; Beckvar *et al.* 2000; Bock *et al.* 2000). In the USFWS survey (unpublished data), MeHg concentrations in 33 *E. complanata* samples ranged from 0.011 : g/g to 0.097 : g/g. The background location for the USFWS collections had a mean MeHg concentration of 0.038 : g/g. The Hg-impacted location for the survey had a mean MeHg level of 0.057 : g/g. The initial concentration of MeHg in *E. complanata* from New Hampshire used by Beckvar *et al.* (2000) in their Sudbury River *in-situ* transplant assessment was 0.024 : g/g. Bock *et al.* (2000) reported MeHg concentrations in *E. complanata* from two sites on the Sudbury River of 0.054 : g/g and 0.052 : g/g.

The MeHg levels in Plow Shop Pond and Nonacoicus Brook, even at the highest concentration, do not appear highly elevated or unusual for the central region of Massachusetts.

6.1.5 Lead (Pb) in Mussels - Lead was not detected in all mussel composite samples. Samples collected in Plow Shop Pond above the dam and in Nonacoicus Brook below the dam had levels ranging from non-detect to 0.09 : g/g. In contrast, the Pb concentrations in mussel composites collected from the terminus of Nonacoicus Brook before the confluence with the Nashua River (NON-10) ranged from 0.96 : g/g to 1.17 : g/g.

In the Dennys River, East Machias River, and Meddybemps Lake in Maine, the Pb concentration in *E. elliptio* and *A. implicata* ranged from 0.19 : g/g to 0.79 : g/g (Mierzykowski *et al.*1998). In New York, Heit *et al.* (1980) reported a mean Pb concentration in *E. complanata* of 2.40 : g/g. Freshwater mussels from 8 locations on the Big Sunflower River in Mississippi had mean Pb concentrations ranging from 0.05 : g/g to 0.10 : g/g (Tatem *et al.* 1994). Anderson (1977) reported Pb concentrations ranging from 3.52 : g/g to 9.63 : g/g in *Lampsilis siliquoidea*, *L. ventricosa*, *Strophitis rugosus*, and *Sphaerium*. Mean Pb in *Anodonta anatina* in the River Thames was 3.98 : g/g (Manly and George 1977).

The Pb concentration in *Lampsilis ventricosa* prior to transplant below mining sites was 0.08 : g/g

(Czarnezki 1987). After a 12-week exposure below the mining sites, the concentration increased to 14.84 : g/g. Mussels collected downstream from 3 metal-discharging industries on the St. Lawrence River, Quebec, had mean Pb concentrations of 2.16 : g/g (range: 1.04 - 3.76 : g/g) in *E. complanata* and 1.21 : g/g (range: 0.32 - 2.64 : g/g) in *Lampsilis radiata* (Metcalf-Smith *et al.* 1996). In a broader survey of 11 sites of differing pollution status on the St. Lawrence River , Metcalf-Smith *et al.* (1996) found Pb ranges in *E. complanata* and *L. radiata* of 0.18 - 2.64 : g/g and 0.14 - 1.50 : g/g, respectively.

The Pb levels in Nonacoicus Brook are not elevated compared to these other studies.

6.2 Crayfish. Crayfish, like mussels, are often used in contaminant investigations. There are several differences, however, between these two organisms in age, mobility, and trophic level. Crayfish (*O. virilis)* have a maximum reported life span of only 40 months (Momot 1988), compared to the 60+ year life span of the *E. elliptio*. While mussels may move only 2 or 3 m in a year, crayfish may move over 120 m in one day (Momot and Gowing 1972). Crayfish are polytrophic - not fitting into any one trophic level (Momot *et al.* 1978). In an aquatic community, they may function as a herbivore, omnivore, and/or carnivore.

Crayfish are important or opportunistic prey items for fish, reptiles, amphibians, birds and mammals. In a study of fish diets in the Sudbury River, Massachusetts (Johnson and Dropkin 1995), crayfish were major prey items that comprised a high percentage of the stomach contents of yellow perch (64%) and largemouth bass (73%). Fish and snapping turtles were important predators on crayfish in a Michigan study (Hazlett *et al.* 1974). In Georgia, stomach analyses of the water snake (*Nerodia sipedon*) indicated substantial foraging on crayfish (Neill 1951). Among birds, great blue heron and belted kingfisher are regular crayfish predators (Hoffman and Curnow 1979, Eipper 1956). Several mammals include crayfish in their diet. Crayfish have been described as the most important animal food for raccoon (Kaufmann 1982). In some areas, crayfish comprise the principal food item for raccoon during the summer (Dorney 1954). Crayfish also comprise a major portion of the river otter's diet (Toweill and Tabor 1982). Another carnivore, the mink, consumes crayfish throughout the year, although the greatest amount of predation by mink occurs during the summer and during drought periods when crayfish are most available (Linscombe *et al.* 1982).

6.2.1 Arsenic (As) in Crayfish - Arsenic levels in crayfish samples from Grove and Plow Shop Ponds ranged from 1.18 : g/g to 1.72 : g/g.

Crayfish (*Procambarus clarkii*) collected from 24 locations in Louisiana bayous and roadway ditches had As residues ranging from 0.38 : g/g[3] to 2.65 : g/g (Naqvi *et al.* 1990). In another Louisiana study, *Procambarus clarkii* and *Procambarus acutus* had mean As levels of 1.47 : g/g and 1.98

[3] If necessary, dry weight crayfish data were converted to wet weight based on 70% moisture.

: g/g in abdominal muscle and hepatopancreas, respectively (Finerty *et al.* 1990). In a western Maryland study of two streams, Mason *et al.* (2000) reported As levels over 1 : g/g in whole crayfish. Analysis of separate tissues showed that As concentrations were highest in crayfish stomach contents and carapace (Mason *et al.* 2000). The mean As levels in crayfish (*Astacus astacus, Pacifasticus leniusculus*) abdominal muscle and hepatopancreas from Sweden were 0.18 : g/g and 0.81 : g/g, respectively (Jorhem *et al.* 1994).

The As concentrations in Grove and Plow Shop Pond crayfish are not elevated compared to other studies.

6.2.2 Cadmium (Cd) in Crayfish - Cadmium concentrations in wholebody crayfish composite samples from Grove Pond and Plow Shop Ponds were 0.56 : g/g and 0.11 : g/g, respectively. The Cd levels in Grove Pond crayfish composites, however, ranged widely from 0.29 : g/g to 1.07 : g/g.

Crayfish have been used in several Cd exposure studies; and pre-exposure, wholebody concentrations were gleaned from these reports. Mirenda (1986) exposed *O. virilis* to waterborne Cd to develop a LC_{50}. Prior to exposure, the control crayfish had Cd burdens of 1.29 : g/g. In the experiment, there was no relationship between the sex or body weight of the crayfish and Cd concentration in the animal (Mirenda 1986). Stinson and Eaton (1983) examined Cd in wholebody *Pacifasticus leniusculus* from Washington and found significant differences in concentrations between males (0.70 : g/g) and females (0.55 : g/g). In a South Carolina accumulation and elimination experiment, the Cd concentration in *Procambarus acutus* prior to exposure was 0.39 : g/g (Giesy *et al.* 1980).

Gale *et al.* (1973) reported Cd ranging from 0.54 : g/g to 1.39 : g/g in wholebody crayfish from southeastern Missouri. Cadmium concentrations in whole *Cambarus bartoni* (minus gut content) collected in lakes 10-km, 30-km, and 150-km from metal smelters in northeastern Ontario were 3.84 : g/g, 3.51 : g/g and 0.87 : g/g, respectively (Alikhan *et al.* 1990). In Illinois, wholebody *O. virilis* had Cd concentrations between 0.31 : g/g and 0.66 : g/g (Anderson and Brower 1978).

In many crayfish contaminant studies, only muscle tissue Cd concentrations are reported. Cadmium concentrations ranged from 0.03 : g/g to 0.12 : g/g in muscle tissue of cave-dwelling crayfish in Tennessee (*O. australis, Cambarus tenebrosus*; Dickson *et al.* 1979). Crayfish (*O. virilis*) from three reference lakes in Ontario had Cd abdominal muscle concentrations ranging from 0.04 : g/g to 0.07 : g/g (France 1987). The mean Cd levels in crayfish (*Astacus astacus, Pacifasticus leniusculus*) abdominal muscle and hepatopancreas from Sweden were < 0.005 : g/g and 0.55 : g/g, respectively (Jorhem *et al.* 1994). In a western Maryland study of two streams, Mason *et al.* (2000) reported Cd levels over 0.49 : g/g in whole crayfish. Analysis of separate crayfish tissues showed that Cd concentrations were highest in the gill and hepatopancreas (Mason *et al.* 2000).

These levels are not elevated compared to values reported in the scientific literature.

6.2.3 Chromium (Cr) in Crayfish - Chromium levels in crayfish samples from Grove Pond and Plow Shop Ponds ranged from 0.48 :g/g to 1.19 :g/g.

Few studies were found in the literature that report Cr levels in crayfish tissue, and none were found reporting wholebody concentrations. In a Cr accumulation study in Spain, *Procambarus clarkii* controls (i.e., unexposed crayfish in the experiment) had Cr concentrations of 3.99 :g/g in gills, 0.30 :g/g in hepatopancreas, 11.46 :g/g in antennal gland, and 0.12 :g/g in tail muscle (Hernández *et al.* 1986). Chromium concentrations ranged from 0.81 :g/g to 0.93 :g/g in muscle tissue of cave-dwelling crayfish in Tennessee (*O. australis, Cambarus tenebrosus*; Dickson *et al.* 1979).

Based on this limited information, the degree of Cr exposure in Plow Shop Pond and Grove Pond wholebody crayfish can not be determined.

6.2.4 Total Mercury (Hg) and Methyl Mercury (MeHg) in Crayfish -

<u>Total mercury</u> - Total Hg in the Plow Shop Pond crayfish composite sample collected near the culvert from Grove Pond (0.05 :g/g) appeared higher than the mean concentration of composite samples collected from the upper end of Grove Pond (0.03 :g/g).

Whole crayfish (*Procambarus acutus*) in Ohio had a mean total Hg concentration of 0.03 :g/g (range: 0.05 - 0.17 :g/g; Hoffman and Curnow 1979). Crayfish from Lousiana had mean mercury concentration of 0.02 :g/g (Schuler *et al.* 2000). Vermeer (1972) reported concentrations in *O. virilis* from waters with pronounced Hg contamination (0.95 :g/g in Clay Lake), moderate pollution (0.08 :g/g in Saskatchewan River) and unpolluted (0.01 :g/g, Lake Winnipegosis). Haines *et al.* (1997) reported a mean total Hg concentration of 0.07 :g/g in crayfish (*Orconectes* spp.) collected from the Sudbury River watershed in Massachusetts.

In several studies, only the Hg content in muscle tissue was reported. Muscle tissue may contain about 3 times as much Hg as the remaining body of a crayfish (Vermeer 1972). In Wisconsin, Hg concentrations in crayfish muscle ranged from 0.07 :g/g to 0.56 :g/g (Sheffy 1978). In 13 south-central Ontario lakes, crayfish (*Cambarus bartoni, C. robustus, O. obscurus, O. propinquus, O. virilis*) had Hg concentrations in abdominal muscle ranging from 0.02 :g/g to 0.61 :g/g (Allard and Stokes 1989). Crayfish (*O. virilis*) in Ontario had Hg concentrations ranging from 0.02 :g/g to 0.05 :g/g in abdominal flexor muscles (Headon *et al.* 1996). In a Saskatchewan study, crayfish tail muscle had Hg concentrations ranging from 0.08 :g/g (background) to 0.22 :g/g (site-impacted; Munro and Gummer 1980). Crayfish (*O. virilis*) from 3 reference lakes in Ontario had Hg abdominal muscle concentrations ranging from 0.06 :g/g to 0.11 :g/g (France 1987).

The Hg level in crayfish from Plow Shop Pond and Grove Pond do not appear elevated compared to regional and other studies.

Methyl mercury - MeHg concentrations exhibited the same pattern between locations as did total Hg, with the MeHg level in the Plow Shop Pond composite sample (0.046 :g/g) appearing higher than the mean of the Grove Pond composite samples (0.027 :g/g). The percentage of MeHg as total Hg was 92% in the Plow Shop Pond sample and ranged from 74 to 122% in the Grove Pond samples.

Two studies were located reporting MeHg levels in crayfish. Mason *et al.* (2000) found MeHg in wholebody crayfish ranged from 0.015 to 0.030 :g/g, with the percentage of MeHg as total Hg ranging from 60 to 75%. Haines *et al.* (1997) reported a mean MeHg concentration of 0.067 :g/g in crayfish (*Orconectes* spp.) collected from the Sudbury River watershed in Massachusetts.

Compared to these two studies, the level of MeHg in crayfish from Grove Pond does not appear elevated. The level in Plow Shop Pond crayfish, however, suggests greater exposure and accumulation of MeHg.

6.2.5 Lead (Pb) in Crayfish - Lead concentrations in 4 crayfish samples from Grove and Plow Shop Ponds ranged from 0.28 :g/g to 0.89 :g/g. The Plow Shop Pond composite sample had the lowest Pb concentration (0.28 :g/g), while the 3 composites samples from Grove Pond appeared dissimilar (0.45 :g/g, 0.67 :g/g, and 0.89 :g/g).

The background level of Pb in crayfish appears to be less than < 0.50 :g/g. In a Missouri study, Schmitt and Finger (1982) suggested a baseline Pb level in crayfish of 0.36 :g/g, and reported a maximum level of 42.0 :g/g. Prior to an uptake experiment, whole crayfish (*O. nais*) from an uncontaminated pond or laboratory-reared contained a Pb concentration of 0.24 :g/g (Knowlton *et al.* 1983). In an earlier Missouri study, Gale *et al.* (1973) reported Pb ranging from 6.30 :g/g to 46.50 :g/g in wholebody crayfish. Anderson and Brower (1978) examined *O. virilis* and found Pb ranging from 2.52 :g/g to 8.22 :g/g. They attributed elevated Pb levels in their background location to motor boats using leaded gasoline.

Compared to wholebody concentrations, Pb levels can be more elevated in specific crayfish tissue. Prior to exposure experiments with *Procambarus clarkii*, Pastor *et al.* (1988) reported Pb levels of 2.07 :g/g in the midgut gland and 78.3 :g/g in the gills of control animals. Crayfish (*O. virilis*) from 3 reference lakes in Ontario had Pb abdominal muscle concentrations ranging from 0.33 :g/g to 0.93 :g/g (France 1987). The mean Pb levels in crayfish (*Astacus astacus, Pacifasticus leniusculus*) abdominal muscle and hepatopancreas from Sweden were 0.02 :g/g and 0.04 :g/g, respectively (Jorhem *et al.* 1994). Lead concentrations ranged from 0.15 :g/g to 0.36 :g/g in muscle tissue of cave-dwelling crayfish in Tennessee (*O. australis, Cambarus tenebrosus*; Dickson *et al.* 1979).

The Pb level in crayfish in Grove Pond and Plow Shop Pond do not appear elevated compared to the studies by Schmitt and Finger (1982) and Knowlton *et al.* (1983).

7. SUMMARY

<u>Mussels</u>

Arsenic, cadmium, chromium, and mercury were detected in all mussel samples (n=12). Lead was detected in only 9 samples. Arsenic concentrations appeared higher in samples from Nonacoicus Brook than in Plow Shop Pond. Concentrations of cadmium, chromium, mercury and lead were similar in 3 of 4 locations. The collection location in Nonacoicus Brook near the confluence of the Nashua River, however, was dissimilar than the other 3 locations and exhibited higher levels of cadmium, chromium, mercury, and lead.

Mussels from Plow Shop Pond and Nonacoicus Brook did not have highly elevated concentrations of arsenic, cadmium, mercury, methyl mercury or lead in their tissues as compared to findings reported elsewhere. However, chromium levels in mussel composite samples collected near the terminus of Nonacoicus Brook (100 meters before the confluence with the Nashua River) were elevated (5.07 : g/g).

<u>Crayfish</u>

Arsenic concentrations in crayfish from the 2 ponds were similar and comparable to levels reported in other studies. Cadmium, chromium, and lead were lower in the composite sample from Plow Shop Pond than the mean concentration of composite samples from Grove Pond. In contrast, mercury levels appeared higher in the Plow Shop Pond sample (0.05 : g/g) than in the Grove Pond samples (Θ 0.03 : g/g). Cadmium, chromium, and lead levels in composite samples from Grove Pond were highly variable. Concentrations of these metals in Grove Pond composite samples differed by factors of 2 (Pb, Cr) or 3 (Cd).

The levels of arsenic, cadmium, mercury and lead in crayfish do not appear to be highly elevated compared to studies reported in the scientific literature. Insufficient information was obtained in the literature review, however, to determine if the chromium levels in crayfish from Grove Pond (Θ 0.85 : g/g) and Plow Shop Pond (0.48 : g/g) are elevated.

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Figures

Figure 1. Mussel sampling locations

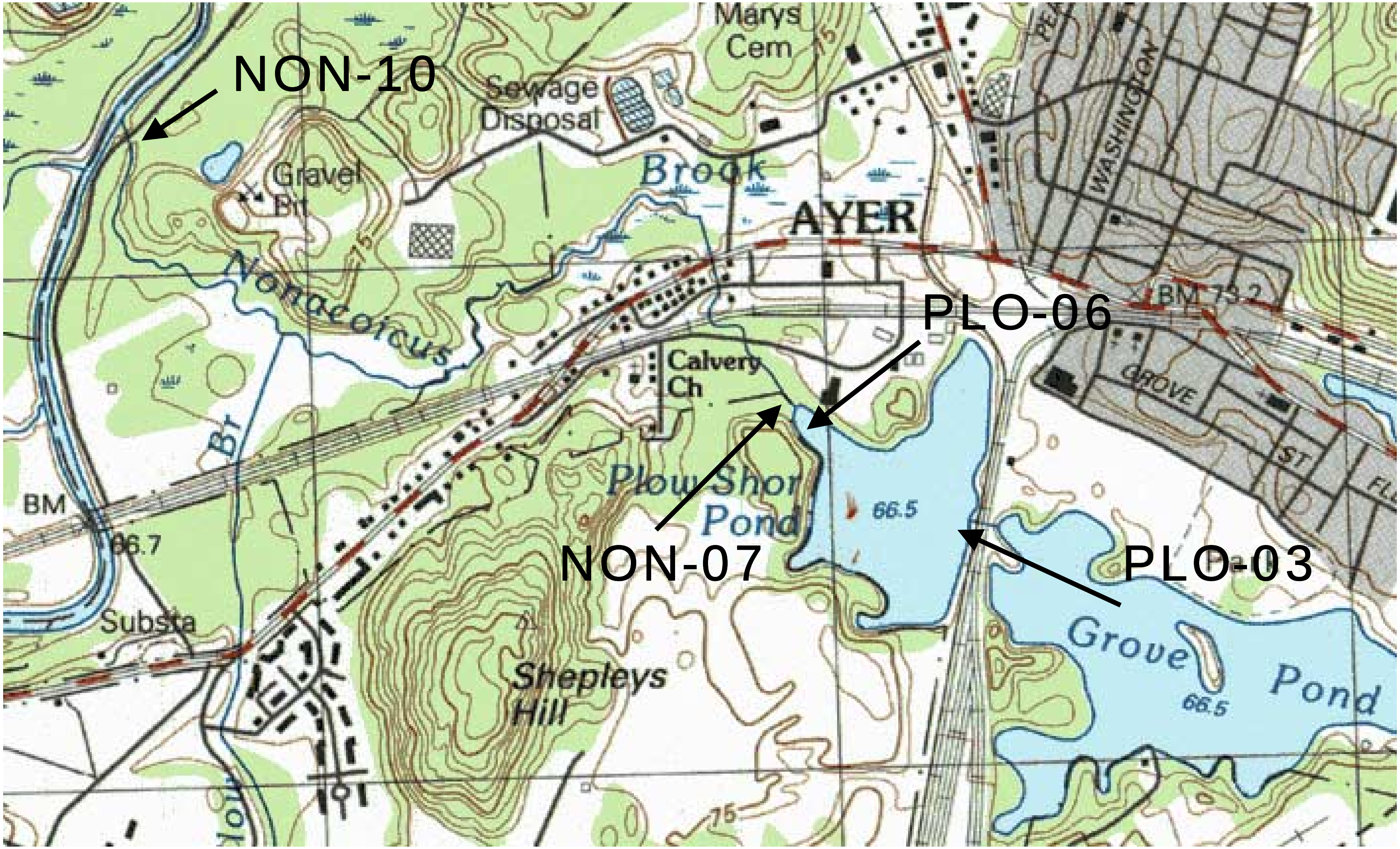
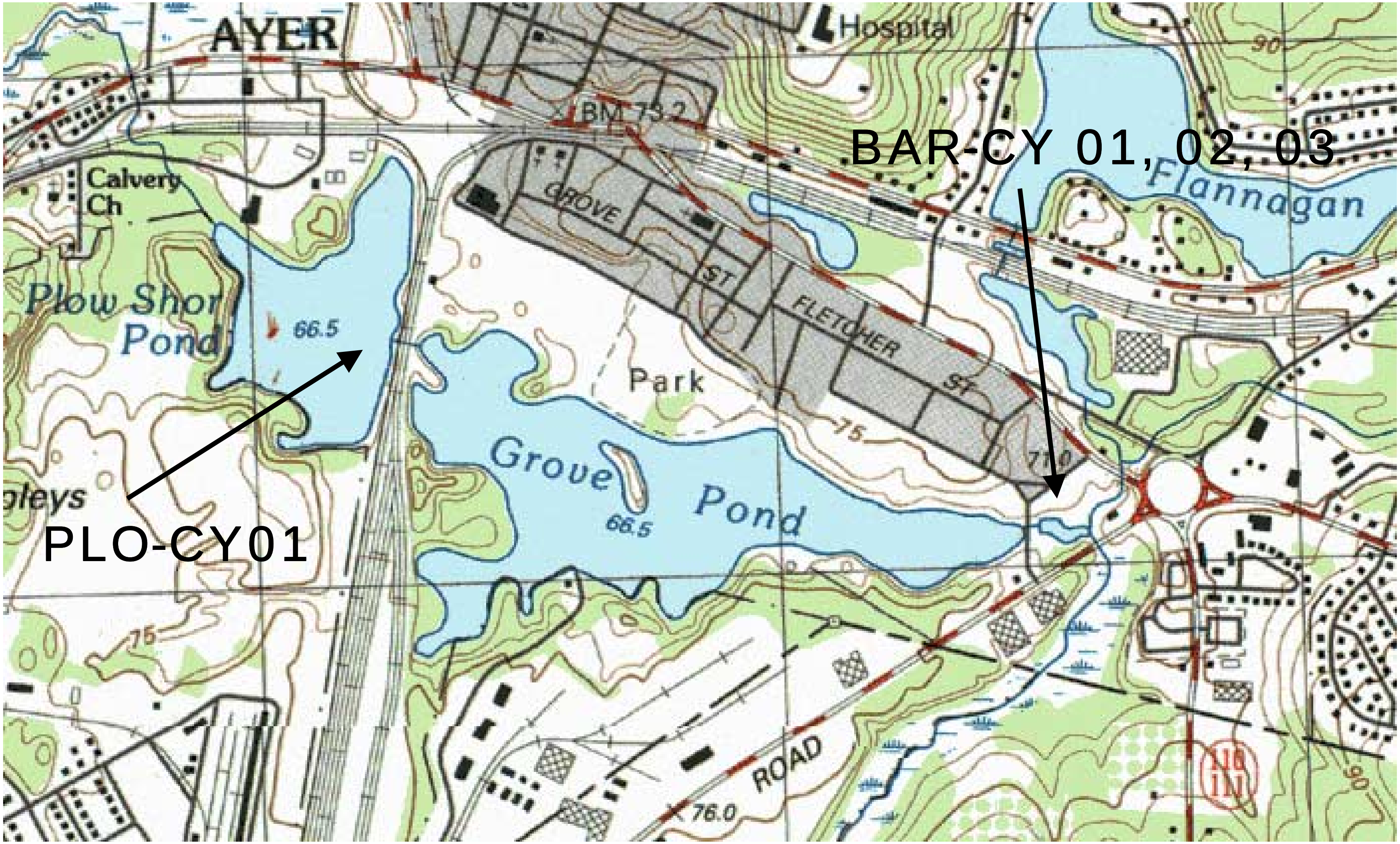


Figure 2. Crayfish sampling locations



Tables

Table 1. Trace elements in wholebody fish from Plow Shop Pond and Grove Pond, *u* g/g WW.

Analyte	Largemouth Bass				Bullhead				Bluegill			
	Plow Shop Pond (n=5)		Grove Pond (n=10)		Plow Shop Pond (n=5)		Grove Pond (n=8)		Plow Shop Pond (n=5)		Grove Pond (n=10)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
As	nd		nd		nc	(nd-0.30)	nc		nc	(nd-1.30)	nd	
Cd	nc	(nd-0.09)	0.05	(0.03-0.88)	nd		0.04	(0.01-0.19)	nd		0.09	(0.05-0.24)
Cr	0.43	(0.32-0.65)	0.51	(0.35-1.16)	0.42	(0.25-0.42)	0.48	(0.29-1.35)	0.66	(0.48-0.93)	0.70	(0.39-1.23)
Cu	0.58	(0.44-0.90)	0.46	(0.29-1.05)	0.76	(0.43-1.30)	0.68	(0.50-1.27)	0.51	(0.44-0.60)	0.58	(0.37-0.79)
Hg	1.40	(0.65-2.70)	0.32	(0.10-1.13)	0.28	(0.09-0.40)	0.04	(0.01-0.14)	0.37	(0.19-0.54)	0.16	(0.08-0.24)
Ni	na		0.19	(0.07-4.15)	na		0.18	(0.05-0.87)	na		0.16	(0.06-0.80)
Pb	nd		0.38	(0.14-4.32)	nc	(nd-0.18)	0.42	(0.18-1.12)	nc	(nd-0.16)	0.48	(0.16-1.38)
Se	0.40	(0.26-0.54)	0.32	(0.22-0.51)	0.27	(0.24-0.31)	0.23	(0.13-0.39)	0.55	(0.42-0.67)	0.33	(0.27-0.38)
Zn	16	(13-19)	12.81	(11.0-16.4)	16	(12-22)	13.17	(10.0-20.5)	25	(22-30)	21.38	(16.7-26.3)

u g/g = parts-per-million, WW = wet weight
nd = non-detect, nc = not calculated (i.e., too few detections), na = not available

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Table 2. Coordinates of Collection Locations

Location/Species/Sample Number(s)	Latitude	Longitude
Plow Shop Pond/Mussel/PLO-03	N 42^{o} 33' 18.48"	W 71^{o} 35' 28.78"
Plow Shop Pond/Mussel/PLO-06	N 42^{o} 33' 25.81"	W 71^{o} 35' 42.51"
Nonacoicus Brook/Mussel/NON-07	N 42^{o} 33' 26.43"	W 71^{o} 35' 43.35"
Nonacoicus Brook/Mussel/NON-10	N 42^{o} 33' 42.43"	W 71^{o} 36' 39.49"
Grove Pond/Crayfish/BAR-CY-01,02,03	N 42^{o} 33' 07.32"	W 71^{o} 34' 32.45"
Plow Shop Pond/Crayfish/PLO-CY-01	N 42^{o} 33' 18.48"	W 71^{o} 35' 28.78"

Mussel = *Elliptio complanata*
Crayfish = *Orconectes* spp.

Table 3. Mussel Metrics - Sample PLO-03
Plow Shop Pond (culvert from Grove Pond)

Sample No.	Total Length (mm)	Total Width (mm)	Total Breadth (mm)	Total Weight (g)	Tissue Weight (g)	Composite Tissue Weight (g)
PLO-03-01A	108.9	60.7	31.6	122	39	
PLO-03-02A	107.5	57.8	30.2	112	32	
PLO-03-03A	101.6	55.3	32.4	106	31	
PLO-03-04A	106.9	55.5	29.0	104	34	
PLO-03-05A	100.2	53.3	32.5	104	32	
Mean	105.0	56.5	31.1	110	34	
PLO-03A						168
PLO-03-01B	98.6	52.1	31.2	96	29	
PLO-03-02B	96.3	53.7	27.6	81	23	
PLO-03-03B	96.6	49.0	27.1	73	24	
PLO-03-04B	96.8	51.3	25.7	79	23	
PLO-03-05B	102.4	50.6	30.0	94	28	
Mean	98.1	51.3	28.3	85	25	
PLO-03B						127
PLO-03-01C	95.9	53.1	31.2	98	27	
PLO-03-02C	92.1	50.4	28.1	75	23	
PLO-03-03C	90.3	46.7	25.1	68	22	
PLO-03-04C	85.6	45.2	25.9	64	20	
PLO-03-05C	84.2	44.7	24.3	57	18	
Mean	89.6	48.0	26.9	72	22	
PLO-03C						110

Table 4. Mussel Metrics - Sample PLO-06
Plow Shop Pond (above dam)

Sample No.	Total Length (mm)	Total Width (mm)	Total Breadth (mm)	Total Weight (g)	Tissue Weight (g)	Composite Tissue Weight (g)
PLO-06-01A	114.4	59.3	31.4	129	47	
PLO-06-02A	110.3	51.0	33.4	117	39	
PLO-06-03A	111.4	61.2	33.1	143	44	
PLO-06-04A	103.6	53.2	33.5	113	39	
PLO-06-05A	100.0	52.1	27.7	82	22	
Mean	107.9	55.4	31.8	117	38	
PLO-06A						191
PLO-06-01B	100.0	51.1	25.8	79	25	
PLO-06-02B	97.5	47.6	28.2	86	26	
PLO-06-03B	97.2	50.3	28.5	91	29	
PLO-06-04B	95.9	52.6	24.7	76	25	
PLO-06-05B	97.2	50.7	27.3	82	28	
Mean	97.6	50.5	26.9	83	27	
PLO-06B						133
PLO-06-01C	94.8	49.9	26.2	72	25	
PLO-06-02C	92.2	44.1	22.6	52	19	
PLO-06-03C	84.0	42.8	22.5	48	15	
PLO-06-04C	86.8	44.2	23.4	54	19	
PLO-06-05C	89.2	44.7	24.6	57	20	
Mean	89.4	45.1	23.9	57	20	
PLO-06C						98

Table 5. Mussel Metrics - Sample NON-07
Nonacoicus Brook (below Plow Shop Pond dam)

Sample No.	Total Length (mm)	Total Width (mm)	Total Breadth (mm)	Total Weight (g)	Tissue Weight (g)	Composite Tissue Weight (g)
NON-07-1A	114.1	60.9	34.9	147	39	
NON-07-2A	105.4	55.8	34.7	132	27	
NON-07-3A	110.4	56.6	32.3	131	36	
NON-07-4A	108.0	54.8	35.0	128	36	
NON-07-5A	94.5	53.9	31.0	109	28	
Mean	106.5	56.4	33.6	129	33	
NON-07A						166
NON-07-1B	105.3	56.6	30.6	114	33	
NON-07-2B	101.7	52.7	34.4	118	31	
NON-07-3B	97.5	55.7	28.8	105	27	
NON-07-4B	94.2	47.6	30.7	96	27	
NON-07-5B	98	52.5	31.5	96	26	
Mean	99.3	53.0	31.2	106	29	
NON-07B						144
NON-07-1C	100.6	54.1	30.6	108	31	
NON-07-2C	100.7	52.4	30.4	108	33	
NON-07-3C	97.4	54.1	32.2	110	30	
NON-07-4C	103.2	51.1	32.5	102	32	
NON-07-5C	96.3	53.7	27.9	93	26	
Mean	99.6	53.1	30.7	104	30	
NON-07C						152

Table 6. Mussel Metrics - Sample NON-10
Nonacoicus Brook (above MacPherson Road)

Sample No.	Total Length (mm)	Total Width (mm)	Total Breadth (mm)	Total Weight (g)	Tissue Weight (g)	Composite Tissue Weight (g)
NON-10-1A	92.6	47.6	24.8	70	18	
NON-10-2A	85.7	48.4	26.3	69	17	
NON-10-3A	81.8	41.5	21.8	41	12	
NON-10-4A	81.5	41.8	24.4	47	14	
NON-10-5A	83.1	43.5	24.2	49	14	
Mean	84.9	44.6	24.3	55	15	
NON-10A						75
NON-10-1B	79.5	46	25.6	54	17	
NON-10-2B	79.4	43.8	23.5	51	12	
NON-10-3B	80.4	41.6	22.3	41	9	
NON-10-4B	78.7	41.5	21.8	41	12	
NON-10-5B	75.3	40.6	20.5	39	10	
Mean	78.7	42.7	22.7	45	12	
NON-10B						60
NON-10-1C	74.5	40.8	22	39	11	
NON-10-2C	77.2	40.6	22.3	41	13	
NON-10-3C	72	41	22.8	41	11	
NON-10-4C	76.5	38.7	19	34	9	
NON-10-5C	72.6	41.5	23.1	43	8	
Mean	74.6	40.5	21.8	40	10	
NON-10C						52

Table 7. Crayfish Metrics - Plow Shop and Grove Pond

Sample No.	Length (mm)	Weight (g)	Composite Sample Weight
PSP Culvert-CY-01	87.5	15	
PSP Culvert-CY-02	79.1	16	
PSP Culvert-CY-03	84.7	16	
PSP Culvert-CY-04	73.6	11	
Mean	81.2	14.5	
SD	6.17	2.38	
PLO-CY-01			**58**
Grove/Barnum-CY-03	83.9	20	
Grove/Barnum-CY-05	80.3	21	
Grove/Barnum-CY-12	83.1	16	
Grove/Barnum-CY-16	77.2	16	
Mean			
SD			
BAR-CY01			**73**
Grove/Barnum-CY-01	90.1	27	
Grove/Barnum-CY-07	90.7	26	
Grove/Barnum-CY-13	88.3	24	
Grove/Barnum-CY-14	90.6	25	
Grove/Barnum-CY-15	86.0	24	
Mean	89.1	25.2	
SD	2.00	1.30	
BAR-CY02			**126**
Grove/Barnum-CY-04	93.5	32	
Grove/Barnum-CY-06	104.3	41	
Grove/Barnum-CY-08	96.8	31	
Grove/Barnum-CY-09	102.2	36	
Mean	99.2	35.0	
SD	4.94	4.55	
BAR-CY03			**140**

SUMMARY TABLES

WET WEIGHT VALUES

Table 8. Trace elements of concern in mussel composite samples, *u* g/g WW.

WET WEIGHT VALUES

Sample No.	As	Cd	Cr	Pb	Hg	MeHg	Ratio MeHg/Hg
Nonacoicus Brook - below Plow Shop Pond dam							
NON-07A	1.01	0.25	0.66	0.09	0.0585	0.0297	0.51
NON-07B	0.89	0.25	0.58	nd	0.0581	0.0286	0.49
NON-07C	1.17	0.20	0.53	nd	0.0609	0.0299	0.49
Mean	1.02	0.24	0.59	nc	0.0592	0.0294	0.50
St Dev	0.140	0.027	0.069		0.00149	0.00072	
Nonacoicus Brook - 100 m. before confluence with Nashua River							
NON-10A	1.13	0.90	5.17	1.16	0.1434	0.0402	0.28
NON-10B	1.01	0.73	4.74	0.96	0.1257	0.0445	0.35
NON-10C	1.17	0.66	5.31	1.17	0.1333	0.0444	0.33
Mean	1.10	0.76	5.07	1.10	0.1341	0.0430	0.32
St Dev	0.084	0.123	0.294	0.120	0.00891	0.00243	
Plow Shop Pond - alongside culvert from Grove Pond							
PLO-03A	0.71	0.39	0.72	0.10	0.0557	0.0264	0.47
PLO-03B	0.66	0.24	0.65	0.07	0.0481	0.0188	0.39
PLO-03C	0.40	0.34	0.68	0.07	0.0411	0.0080	0.19
Mean	0.59	0.32	0.68	0.08	0.0483	0.0177	0.35
St Dev	0.168	0.074	0.036	0.014	0.00725	0.00926	
Plow Shop Pond - above Plow Shop Pond dam							
PLO-06A	0.79	0.34	0.44	0.06	0.0434	0.0073	0.17
PLO-06B	0.93	0.36	0.70	0.06	0.0413	0.0117	0.28
PLO-06C	0.83	0.19	0.55	nd	0.0427	0.0071	0.17
Mean	0.85	0.30	0.57	nc	0.0425	0.0087	0.21
St Dev	0.074	0.095	0.130		0.00108	0.00261	

u g/g = ppm, WW = wet weight
nd = non-detect, nc = not calculated
All mussels were Eastern Elliptio (*Elliptio complanata*)

Table 9. Trace elements of concern in crayfish composite samples, *u* g/g WW.

WET WEIGHT VALUES

Sample No.	As	Cd	Cr	Pb	Hg	MeHg	Ratio MeHg/Hg
Grove Pond - below Barnum Gate bridge							
BAR-CY01	1.18	1.07	1.19	0.89	0.0244	0.0255	1.05
BAR-CY02	1.33	0.31	0.80	0.45	0.0218	0.0266	1.22
BAR-CY03	1.72	0.29	0.56	0.67	0.0349	0.0257	0.74
Mean	1.41	0.56	0.85	0.67	0.0270	0.0260	0.96
St Dev	0.282	0.446	0.317	0.216	0.00692	0.00058	
Plow Shop Pond - alongside culvert from Grove Pond							
PLO-CY01	1.62	0.11	0.48	0.28	0.0465	0.0429	0.92

u g/g = ppm, WW = wet weight

All crayfish were from the genus *Orconectes* spp.

Table 10. Other trace elements in mussel composite samples, *u* g/g WW

WET WEIGHT VALUES

Sample No.	Al	B	Ba	Cu	Fe	Mg	Mn	Ni	Se	Sr	Zn
Nonacoicus Brook - below Plow Shop Pond dam											
NON-7A	nd	nd	61.4	0.65	667	129.0	870	nd	0.16	18.1	21.2
NON-7B	nd	nd	46.9	0.58	503	124.0	692	nd	0.16	15.7	19.5
NON-7C	nd	nd	44.6	0.57	574	110.0	581	nd	0.21	13.6	17.7
Mean	nd	nd	51.0	0.60	581	121.0	714	nd	0.18	15.8	19.5
St Dev			9.108	0.047	82.2	9.85	145.8		0.025	2.25	1.75
Nonacoicus Brook - 100 m. before confluence with Nashua River											
NON-10A	35.90	nd	65.4	1.33	727	130.0	976	0.19	0.31	21.0	24.6
NON-10B	32.60	nd	53.9	1.16	606	119.0	942	0.20	0.31	18.2	22.0
NON-10C	40.40	nd	53.0	1.50	678	124.0	1079	0.21	0.32	19.3	22.5
Mean	36.30	nd	57.4	1.33	670	124.3	999	0.20	0.31	19.5	23.0
St Dev	3.915		6.91	0.170	60.9	5.51	71.3	0.008	0.005	1.41	1.38
Plow Shop Pond - alongside culvert from Grove Pond											
PLO-03A	1.12	0.40	84.8	0.64	1002	110.0	1042	0.11	0.17	25.4	21.7
PLO-03B	nd	0.35	80.5	0.75	1103	119.0	791	nd	0.15	23.7	21.8
PLO-03C	nd	0.47	95.1	0.68	1372	89.5	862	0.12	0.17	26.2	17.8
Mean	nc	0.40	86.8	0.69	1159	106.2	898	nc	0.16	25.1	20.4
St Dev	nc	0.058	7.50	0.054	191.3	15.12	129.4	nc	0.013	1.28	2.28
Plow Shop Pond - above Plow Shop Pond dam											
PLO-06A	nd	nd	55.9	0.63	643	81.1	509	0.10	0.18	12.4	14.6
PLO-06B	nd	nd	51.3	0.76	623	96.7	631	0.15	0.18	15.3	17.3
PLO-06C	nd	nd	32.0	0.73	364	104.0	593	nd	0.18	12.0	18.6
Mean	nd	nd	46.4	0.71	543	93.9	578	nc	0.18	13.2	16.8
St Dev			12.68	0.066	155.6	11.70	62.43	nc	0.003	1.80	2.04

u g/g = ppm, WW = wet weight
nd = non-detect, nc = not calculated
All mussels are Eastern Elliptio (*Elliptio complanata*)

Table 11. Other trace elements in crayfish composite samples, *u* g/g WW

WET WEIGHT VALUES

Sample No.	Al	B	Ba	Cu	Fe	Mg	Mn	Ni	Se	Sr	Zn
Grove Pond - below Barnum Gate Bridge											
BAR-CY01	30.00	nd	37.5	25.40	224.0	402.0	726.0	2.14	nd	120.0	34.7
BAR-CY02	20.60	nd	25.6	16.00	224.0	382.0	647.0	0.88	nd	145.0	25.5
BAR-CY03	29.60	nd	28.5	15.50	332.0	404.0	785.0	0.76	nd	156.0	25.0
Mean	26.73	nd	30.5	18.97	260.0	396.0	719.3	1.26		140.3	28.4
St Dev	5.315		6.21	5.577	62.35	12.17	69.24	0.762		18.45	5.46
Plow Shop Pond - alongside culvert from Grove Pond											
PLO-CY01	2.94	nd	37.7	24.40	349.0	388.0	278.0	0.27	nd	157.0	23.3

u g/g = ppm, WW = wet weight
nd = non-detect
All crayfish were from the genus *Orconectes* sp.

SUMMARY TABLES

DRY WEIGHT VALUES

Table 12. Trace elements of concern in mussel composite samples, *u* g/g DW.

DRY WEIGHT VALUES

Sample No.	% Moisture	As	Cd	Cr	Pb	Hg	MeHg	Ratio MeHg/Hg
Nonacoicus Brook - below Plow Shop Pond dam								
NON-07A	82.0	5.63	1.41	3.68	0.51	0.325	0.165	0.51
NON-07B	83.0	5.24	1.47	3.39	nd	0.342	0.168	0.49
NON-07C	82.2	6.57	1.15	2.96	nd	0.342	0.168	0.49
Mean		5.81	1.34	3.34	nc	0.336	0.167	0.50
St Dev		0.684	0.170	0.362		0.0098	0.0017	
Nonacoicus Brook - 100 m. before confluence with Nashua River								
NON-10A	84.1	7.13	5.64	32.50	7.32	0.902	0.253	0.28
NON-10B	84.6	6.55	4.71	30.80	6.24	0.816	0.289	0.35
NON-10C	84.7	7.64	4.31	34.70	7.66	0.871	0.290	0.33
Mean		7.11	4.89	32.67	7.07	0.863	0.277	0.32
St Dev		0.545	0.682	1.955	0.741	0.0436	0.0211	
Plow Shop Pond - alongside culvert from Grove Pond								
PLO-03A	85.0	4.73	2.58	4.80	0.65	0.371	0.176	0.47
PLO-03B	86.7	4.96	1.82	4.88	0.53	0.362	0.141	0.39
PLO-03C	87.3	3.12	2.70	5.32	0.59	0.324	0.063	0.19
Mean		4.27	2.37	5.00	0.59	0.352	0.127	0.36
St Dev		1.003	0.477	0.280	0.060	0.0249	0.0580	
Plow Shop Pond - above Plow Shop Pond dam								
PLO-06A	84.5	5.09	2.19	2.86	0.41	0.280	0.047	0.17
PLO-06B	85.2	6.30	2.46	4.74	0.39	0.279	0.079	0.28
PLO-06C	84.9	5.48	1.25	3.66	nd	0.283	0.047	0.17
Mean		5.62	1.97	3.75	nc	0.281	0.058	0.21
St Dev		0.618	0.635	0.943		0.0021	0.0186	

u g/g = ppm, DW = dry weight
nd = non-detect, nc = not calculated
All mussels were Eastern Elliptio (*Elliptio complanata*)

Table 13. Trace elements of concern in crayfish composite samples, *u* g/g DW.

DRY WEIGHT VALUES

Sample No.	% Moisture	As	Cd	Cr	Pb	Hg	MeHg	Ratio MeHg/Hg
Grove Pond - below Barnum Gate bridge								
BAR-CY01	72.9	4.35	3.95	4.38	3.27	0.0899	0.0942	1.05
BAR-CY02	69.3	4.32	1.00	2.62	1.48	0.0711	0.0867	1.22
BAR-CY03	68.0	5.39	0.90	1.74	2.08	0.1090	0.0804	0.74
Mean		4.69	1.95	2.91	2.28	0.0900	0.0871	0.97
St Dev		0.609	1.732	1.344	0.911	0.01895	0.00691	
Plow Shop Pond - alongside culvert from Grove Pond								
PLO-CY01	70.4	5.47	0.37	1.62	0.96	0.1570	0.1450	0.92

u g/g = ppm, DW = dry weight
All crayfish were from the genus *Orconectes* spp.

Table 14. Other trace elements in mussel composite samples, *u* g/g DW

DRY WEIGHT VALUES

Sample No.	Al	B	Ba	Cu	Fe	Mg	Mn	Ni	Se	Sr	Zn
Nonacoicus Brook - below Plow Shop Pond dam											
NON-7A	nd	nd	341	3.63	3706	714	4833	nd	0.91	100.0	118.0
NON-7B	nd	nd	276	3.40	2958	732	4073	nd	0.94	92.4	115.0
NON-7C	nd	nd	251	3.19	3223	620	3264	nd	1.16	76.3	99.4
Mean	nd	nd	289	3.41	3296	689	4057	nd	1.00	89.6	110.8
St Dev			46.5	0.220	379.3	60.1	784.6		0.137	12.10	9.99
Nonacoicus Brook - 100 m. before confluence with Nashua River											
NON-10A	226.0	nd	411	8.37	4572	820	6140	1.20	1.94	132.0	155.0
NON-10B	212.0	nd	350	7.54	3934	773	6119	1.31	1.98	118.0	143.0
NON-10C	264.0	nd	347	9.79	4432	810	7051	1.36	2.06	126.0	147.0
Mean	234.0	nd	369	8.57	4313	801	6437	1.29	1.99	125.3	148.3
St Dev	26.91		36.1	1.138	335.3	24.8	532.1	0.082	0.061	7.02	6.11
Plow Shop Pond - alongside culvert from Grove Pond											
PLO-03A	7.48	2.65	565	4.29	6683	730	6949	0.74	1.11	169.0	145.0
PLO-03B	nd	2.63	605	5.65	8291	898	5947	nd	1.10	178.0	164.0
PLO-03C	nd	3.67	749	5.36	10805	705	6788	0.93	1.34	206.0	140.0
Mean	nc	2.98	640	5.10	8593	778	6561	nc	1.18	184.3	149.7
St Dev		0.595	96.8	0.716	2077.5	105.0	538.1		0.136	19.30	12.66
Plow Shop Pond - above Plow Shop Pond dam											
PLO-06A	nd	nd	361	4.08	4147	523	3287	0.66	1.18	79.8	94.0
PLO-06B	nd	nd	347	5.11	4208	654	4262	1.01	1.20	104.0	117.0
PLO-06C	nd	nd	212	4.84	2413	688	3928	nd	1.17	79.7	124.0
Mean	nd	nd	307	4.68	3589	622	3826	nc	1.18	87.8	111.7
St Dev			82.3	0.534	1019.2	87.1	495.5		0.015	14.00	15.70

u g/g = ppm, DW = dry weight
nd = non-detect, nc = not calculated
All mussels are Eastern Elliptio (*Elliptio complanata*)

Table 15. Other trace elements in crayfish composite samples, *u* g/g DW

DRY WEIGHT VALUES

Sample No.	Al	B	Ba	Cu	Fe	Mg	Mn	Ni	Se	Sr	Zn
Grove Pond - below Barnum Gate bridge											
BAR-CY01	111.00	nd	138.0	93.70	825.0	1484.0	2679.0	7.88	nd	442.0	128.0
BAR-CY02	67.00	nd	83.4	52.10	730.0	1244.0	2107.0	2.88	nd	472.0	83.2
BAR-CY03	92.60	nd	88.9	48.30	1006.0	1262.0	2452.0	2.38	nd	487.0	78.1
Mean	90.20	nd	103.4	64.70	853.7	1330.0	2412.7	4.38	nd	467.0	96.4
St Dev	22.098		30.06	25.187	140.22	133.67	288.02	3.041		22.91	27.46
Plow Shop Pond - alongside culvert from Grove Pond											
PLO-CY01	9.92	nd	128.0	82.40	1180.0	1312.0	940.0	0.92	nd	530.0	78.7

u g/g = ppm, DW = dry weight
nd = non-detect
All crayfish were from the genus *Orconectes* sp.

APPENDIX

LABORATORY REPORT

ECDMS ANALYTICAL REPORT
04/27/99

Catalog	Regional Study Id	Purchase Order	User Id	Lab Id
5030086	5F01	92223-99-Y363	R5NEFO	RTI

- Catalog Submitter: Steve Mierzykowski - Concord, NH

- Lab Name: Research Triangle Institute (RTI)

- Sections included in the report:

  - WEIGHT, % MOISTURE, ETC.
  - PROCEDURAL BLANKS
  - REFERENCE MATERIALS
  - QA/QC ANOMALIES
  - CONTAMINANT CONCENTRATIONS
  - DUPLICATES
  - SPIKE RECOVERIES
  - ANALYTICAL METHODS

- Sections NOT included (NO DATA were found):

  - SOIL/SEDIMENT PARAMETERS
  - RESULT MODIFERS

- Report Status:

  - ALL results are reported as 3 significant digits.

Pages	Results Rounded	Results too Large to Print	Lines Per Page	Columns Per Row
24	0	0	53	78

------------------- Symbols and Abbreviations Used --------------------

- The following may appear before a reported result (ex. < 1.234).

  < = Actual result is less than the reported detection limit.
  > = Actual result is greater than the result reported.

- Rounded results are preceded by an '*' (example: *.0253). Results were rounded in order to fit within the column and line widths used in the report.

- Results too large to print are represented by a series of '*' (example: ********). These values could not be rounded small enough to fit within the column and line widths used in the report.

WEIGHT, % MOISTURE, ETC.

Sample Number	Sample Matrix	Sample Weight(g)	Percent Moisture
BAR-CY01	Invertebrate	79	72.9
BAR-CY02	Invertebrate	132	69.3
BAR-CY03	Invertebrate	146	68.0
NON-07A	Invertebrate	166	82.0
NON-07B	Invertebrate	143	83.0
NON-07C	Invertebrate	152	82.2
NON-10A	Invertebrate	71	84.1
NON-10B	Invertebrate	61	84.6
NON-10C	Invertebrate	52	84.7
PLO-03A	Invertebrate	166	85.0
PLO-03B	Invertebrate	126	86.7
PLO-03C	Invertebrate	108	87.3
PLO-06A	Invertebrate	188	84.5
PLO-06B	Invertebrate	131	85.2
PLO-06C	Invertebrate	98	84.9
PLO-CY01	Invertebrate	64	70.4

CONTAMINANT CONCENTRATIONS

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
Al	BAR-CY01	Invertebrate	111.	6.08	30.0	1.65
	BAR-CY02	Invertebrate	67.0	5.71	20.6	1.75
	BAR-CY03	Invertebrate	92.6	5.91	29.6	1.89
	NON-07A	Invertebrate	< 6.01	6.01	< 1.08	1.08
	NON-07B	Invertebrate	< 6.14	6.14	< 1.04	1.04
	NON-07C	Invertebrate	< 6.20	6.20	< 1.10	1.10
	NON-10A	Invertebrate	226.	5.88	35.9	.935
	NON-10B	Invertebrate	212.	6.01	32.6	.925
	NON-10C	Invertebrate	264.	6.17	40.4	.944
	PLO-03A	Invertebrate	7.48	6.04	1.12	.906
	PLO-03B	Invertebrate	< 5.97	5.97	< .794	.794
	PLO-03C	Invertebrate	< 5.94	5.94	< .754	.754
	PLO-06A	Invertebrate	< 6.10	6.10	< .945	.945
	PLO-06B	Invertebrate	< 6.43	6.43	< .951	.951
	PLO-06C	Invertebrate	< 6.20	6.20	< .937	.937
	PLO-CY01	Invertebrate	9.92	6.31	2.94	1.87
As	BAR-CY01	Invertebrate	4.35	.608	1.18	.165
	BAR-CY02	Invertebrate	4.32	.571	1.33	.175
	BAR-CY03	Invertebrate	5.39	.591	1.72	.189
	NON-07A	Invertebrate	5.63	.601	1.01	.108
	NON-07B	Invertebrate	5.24	.614	.891	.104
	NON-07C	Invertebrate	6.57	.620	1.17	.110
	NON-10A	Invertebrate	7.13	.588	1.13	.0935
	NON-10B	Invertebrate	6.55	.601	1.01	.0926
	NON-10C	Invertebrate	7.64	.617	1.17	.0944
	PLO-03A	Invertebrate	4.73	.604	.710	.0906
	PLO-03B	Invertebrate	4.96	.597	.660	.0794
	PLO-03C	Invertebrate	3.12	.594	.396	.0754
	PLO-06A	Invertebrate	5.09	.610	.789	.0945
	PLO-06B	Invertebrate	6.30	.643	.932	.0951
	PLO-06C	Invertebrate	5.48	.620	.827	.0937
	PLO-CY01	Invertebrate	5.47	.631	1.62	.187
B	BAR-CY01	Invertebrate	< 2.43	2.43	< .659	.659
	BAR-CY02	Invertebrate	< 2.28	2.28	< .701	.701
	BAR-CY03	Invertebrate	< 2.36	2.36	< .757	.757
	NON-07A	Invertebrate	< 2.40	2.40	< .433	.433
	NON-07B	Invertebrate	< 2.46	2.46	< .418	.418
	NON-07C	Invertebrate	< 2.48	2.48	< .442	.442
	NON-10A	Invertebrate	< 2.35	2.35	< .374	.374
	NON-10B	Invertebrate	< 2.40	2.40	< .370	.370
	NON-10C	Invertebrate	< 2.47	2.47	< .378	.378
	PLO-03A	Invertebrate	2.65	2.42	.398	.362
	PLO-03B	Invertebrate	2.63	2.39	.350	.317
	PLO-03C	Invertebrate	3.67	2.38	.466	.302

CONTAMINANT CONCENTRATIONS (Cont.)

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
B	PLO-06A	Invertebrate	< 2.44	2.44	< .378	.378
	PLO-06B	Invertebrate	< 2.57	2.57	< .380	.380
	PLO-06C	Invertebrate	< 2.48	2.48	< .375	.375
	PLO-CY01	Invertebrate	< 2.53	2.53	< .747	.747
Ba	BAR-CY01	Invertebrate	138.	.608	37.5	.165
	BAR-CY02	Invertebrate	83.4	.571	25.6	.175
	BAR-CY03	Invertebrate	88.9	.591	28.5	.189
	NON-07A	Invertebrate	341.	.601	61.4	.108
	NON-07B	Invertebrate	276.	.614	46.9	.104
	NON-07C	Invertebrate	251.	.620	44.6	.110
	NON-10A	Invertebrate	411.	.588	65.4	.0935
	NON-10B	Invertebrate	350.	.601	53.9	.0926
	NON-10C	Invertebrate	347.	.617	53.0	.0944
	PLO-03A	Invertebrate	565.	.604	84.8	.0906
	PLO-03B	Invertebrate	605.	.597	80.5	.0794
	PLO-03C	Invertebrate	749.	.594	95.1	.0754
	PLO-06A	Invertebrate	361.	.610	55.9	.0945
	PLO-06B	Invertebrate	347.	.643	51.3	.0951
	PLO-06C	Invertebrate	212.	.620	32.0	.0937
	PLO-CY01	Invertebrate	128.	.631	37.7	.187
Be	BAR-CY01	Invertebrate	< .122	.122	< .0330	.0330
	BAR-CY02	Invertebrate	< .114	.114	< .0351	.0351
	BAR-CY03	Invertebrate	< .118	.118	< .0378	.0378
	NON-07A	Invertebrate	< .120	.120	< .0216	.0216
	NON-07B	Invertebrate	< .123	.123	< .0209	.0209
	NON-07C	Invertebrate	< .124	.124	< .0221	.0221
	NON-10A	Invertebrate	< .118	.118	< .0187	.0187
	NON-10B	Invertebrate	< .120	.120	< .0185	.0185
	NON-10C	Invertebrate	< .124	.124	< .0189	.0189
	PLO-03A	Invertebrate	< .121	.121	< .0181	.0181
	PLO-03B	Invertebrate	< .119	.119	< .0159	.0159
	PLO-03C	Invertebrate	< .119	.119	< .0151	.0151
	PLO-06A	Invertebrate	< .122	.122	< .0189	.0189
	PLO-06B	Invertebrate	< .128	.128	< .0190	.0190
	PLO-06C	Invertebrate	< .124	.124	< .0187	.0187
	PLO-CY01	Invertebrate	< .126	.126	< .0374	.0374
Cd	BAR-CY01	Invertebrate	3.95	.122	1.07	.0330
	BAR-CY02	Invertebrate	1.00	.114	.308	.0351
	BAR-CY03	Invertebrate	.901	.118	.288	.0378
	NON-07A	Invertebrate	1.41	.120	.254	.0216
	NON-07B	Invertebrate	1.47	.123	.250	.0209
	NON-07C	Invertebrate	1.15	.124	.205	.0221
	NON-10A	Invertebrate	5.64	.118	.896	.0187

CONTAMINANT CONCENTRATIONS (Cont.)

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
Cd	NON-10B	Invertebrate	4.71	.120	.725	.0185
	NON-10C	Invertebrate	4.31	.124	.660	.0189
	PLO-03A	Invertebrate	2.58	.121	.386	.0181
	PLO-03B	Invertebrate	1.82	.119	.243	.0159
	PLO-03C	Invertebrate	2.70	.119	.343	.0151
	PLO-06A	Invertebrate	2.19	.122	.339	.0189
	PLO-06B	Invertebrate	2.46	.128	.364	.0190
	PLO-06C	Invertebrate	1.25	.124	.189	.0187
	PLO-CY01	Invertebrate	.368	.126	.109	.0374
Cr	BAR-CY01	Invertebrate	4.38	.608	1.19	.165
	BAR-CY02	Invertebrate	2.62	.571	.805	.175
	BAR-CY03	Invertebrate	1.74	.591	.558	.189
	NON-07A	Invertebrate	3.68	.601	.663	.108
	NON-07B	Invertebrate	3.39	.614	.576	.104
	NON-07C	Invertebrate	2.96	.620	.526	.110
	NON-10A	Invertebrate	32.5	.588	5.16	.0935
	NON-10B	Invertebrate	30.8	.601	4.74	.0926
	NON-10C	Invertebrate	34.7	.617	5.31	.0944
	PLO-03A	Invertebrate	4.80	.604	.720	.0906
	PLO-03B	Invertebrate	4.88	.597	.650	.0794
	PLO-03C	Invertebrate	5.32	.594	.676	.0754
	PLO-06A	Invertebrate	2.86	.610	.443	.0945
	PLO-06B	Invertebrate	4.74	.643	.701	.0951
	PLO-06C	Invertebrate	3.66	.620	.553	.0937
	PLO-CY01	Invertebrate	1.62	.631	.480	.187
Cu	BAR-CY01	Invertebrate	93.7	.608	25.4	.165
	BAR-CY02	Invertebrate	52.1	.571	16.0	.175
	BAR-CY03	Invertebrate	48.3	.591	15.5	.189
	NON-07A	Invertebrate	3.63	.601	.654	.108
	NON-07B	Invertebrate	3.40	.614	.578	.104
	NON-07C	Invertebrate	3.19	.620	.567	.110
	NON-10A	Invertebrate	8.37	.588	1.33	.0935
	NON-10B	Invertebrate	7.54	.601	1.16	.0926
	NON-10C	Invertebrate	9.79	.617	1.50	.0944
	PLO-03A	Invertebrate	4.29	.604	.644	.0906
	PLO-03B	Invertebrate	5.65	.597	.751	.0794
	PLO-03C	Invertebrate	5.36	.594	.680	.0754
	PLO-06A	Invertebrate	4.08	.610	.632	.0945
	PLO-06B	Invertebrate	5.11	.643	.756	.0951
	PLO-06C	Invertebrate	4.84	.620	.731	.0937
	PLO-CY01	Invertebrate	82.4	.631	24.4	.187
Fe	BAR-CY01	Invertebrate	825.	12.2	224.	3.30
	BAR-CY02	Invertebrate	730.	11.4	224.	3.50

CONTAMINANT CONCENTRATIONS (Cont.)

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
Fe	BAR-CY03	Invertebrate	1006	11.8	322.	3.78
	NON-07A	Invertebrate	3706	12.0	667.	2.16
	NON-07B	Invertebrate	2958	12.3	503.	2.09
	NON-07C	Invertebrate	3223	12.4	574.	2.21
	NON-10A	Invertebrate	4572	11.8	727.	1.87
	NON-10B	Invertebrate	3934	12.0	606.	1.85
	NON-10C	Invertebrate	4432	12.3	678.	1.89
	PLO-03A	Invertebrate	6683	12.1	1002	1.81
	PLO-03B	Invertebrate	8291	11.9	1103	1.59
	PLO-03C	Invertebrate	10805	11.9	1372	1.51
	PLO-06A	Invertebrate	4147	12.2	643.	1.89
	PLO-06B	Invertebrate	4208	12.9	623.	1.90
	PLO-06C	Invertebrate	2413	12.4	364.	1.87
	PLO-CY01	Invertebrate	1180	12.6	349.	3.74
Hg	BAR-CY01	Invertebrate	.0899	.0243	.0244	.00659
	BAR-CY02	Invertebrate	.0711	.0228	.0218	.00700
	BAR-CY03	Invertebrate	.109	.0236	.0349	.00755
	NON-07A	Invertebrate	.325	.0240	.0585	.00432
	NON-07B	Invertebrate	.342	.0246	.0582	.00418
	NON-07C	Invertebrate	.342	.0248	.0610	.00441
	NON-10A	Invertebrate	.902	.0235	.143	.00374
	NON-10B	Invertebrate	.816	.0240	.126	.00370
	NON-10C	Invertebrate	.871	.0247	.133	.00378
	PLO-03A	Invertebrate	.371	.0242	.0556	.00363
	PLO-03B	Invertebrate	.362	.0239	.0482	.00318
	PLO-03C	Invertebrate	.324	.0240	.0412	.00305
	PLO-06A	Invertebrate	.280	.0244	.0433	.00378
	PLO-06B	Invertebrate	.279	.0257	.0413	.00380
	PLO-06C	Invertebrate	.283	.0248	.0428	.00374
	PLO-CY01	Invertebrate	.157	.0253	.0466	.00749
Mg	BAR-CY01	Invertebrate	1484	12.2	402.	3.30
	BAR-CY02	Invertebrate	1244	11.4	382.	3.50
	BAR-CY03	Invertebrate	1262	11.8	404.	3.78
	NON-07A	Invertebrate	714.	12.0	129.	2.16
	NON-07B	Invertebrate	732.	12.3	124.	2.09
	NON-07C	Invertebrate	620.	12.4	110.	2.21
	NON-10A	Invertebrate	820.	11.8	130.	1.87
	NON-10B	Invertebrate	773.	12.0	119.	1.85
	NON-10C	Invertebrate	810.	12.3	124.	1.89
	PLO-03A	Invertebrate	730.	12.1	110.	1.81
	PLO-03B	Invertebrate	898.	11.9	119.	1.59
	PLO-03C	Invertebrate	705.	11.9	89.5	1.51
	PLO-06A	Invertebrate	523.	12.2	81.1	1.89
	PLO-06B	Invertebrate	654.	12.9	96.7	1.90

CONTAMINANT CONCENTRATIONS (Cont.)

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
Mg	PLO-06C	Invertebrate	688.	12.4	104.	1.87
	PLO-CY01	Invertebrate	1312	12.6	388.	3.74
Mn	BAR-CY01	Invertebrate	2679	.487	726.	.132
	BAR-CY02	Invertebrate	2107	.457	647.	.140
	BAR-CY03	Invertebrate	2452	.473	785.	.151
	NON-07A	Invertebrate	4833	.481	870.	.0865
	NON-07B	Invertebrate	4073	.491	692.	.0835
	NON-07C	Invertebrate	3264	.496	581.	.0883
	NON-10A	Invertebrate	6140	.471	976.	.0748
	NON-10B	Invertebrate	6119	.481	942.	.0740
	NON-10C	Invertebrate	7051	.494	1079	.0756
	PLO-03A	Invertebrate	6949	.483	1042	.0725
	PLO-03B	Invertebrate	5947	.477	791.	.0635
	PLO-03C	Invertebrate	6788	.475	862.	.0603
	PLO-06A	Invertebrate	3287	.488	509.	.0756
	PLO-06B	Invertebrate	4262	.514	631.	.0761
	PLO-06C	Invertebrate	3928	.496	593.	.0749
	PLO-CY01	Invertebrate	940.	.505	278.	.150
Mo	BAR-CY01	Invertebrate	< .608	.608	< .165	.165
	BAR-CY02	Invertebrate	< .571	.571	< .175	.175
	BAR-CY03	Invertebrate	.862	.591	.276	.189
	NON-07A	Invertebrate	< .601	.601	< .108	.108
	NON-07B	Invertebrate	< .614	.614	< .104	.104
	NON-07C	Invertebrate	< .620	.620	< .110	.110
	NON-10A	Invertebrate	< .588	.588	< .0935	.0935
	NON-10B	Invertebrate	.758	.601	.117	.0926
	NON-10C	Invertebrate	.628	.617	.0960	.0944
	PLO-03A	Invertebrate	< .604	.604	< .0906	.0906
	PLO-03B	Invertebrate	< .597	.597	< .0794	.0794
	PLO-03C	Invertebrate	< .594	.594	< .0754	.0754
	PLO-06A	Invertebrate	< .610	.610	< .0945	.0945
	PLO-06B	Invertebrate	< .643	.643	< .0951	.0951
	PLO-06C	Invertebrate	< .620	.620	< .0937	.0937
	PLO-CY01	Invertebrate	< .631	.631	< .187	.187
Ni	BAR-CY01	Invertebrate	7.88	.608	2.14	.165
	BAR-CY02	Invertebrate	2.88	.571	.884	.175
	BAR-CY03	Invertebrate	2.38	.591	.763	.189
	NON-07A	Invertebrate	< .601	.601	< .108	.108
	NON-07B	Invertebrate	< .614	.614	< .104	.104
	NON-07C	Invertebrate	< .620	.620	< .110	.110
	NON-10A	Invertebrate	1.20	.588	.192	.0935
	NON-10B	Invertebrate	1.31	.601	.201	.0926
	NON-10C	Invertebrate	1.36	.617	.208	.0944

CONTAMINANT CONCENTRATIONS (Cont.)

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
Ni	PLO-03A	Invertebrate	.738	.604	.111	.0906
	PLO-03B	Invertebrate	< .597	.597	< .0794	.0794
	PLO-03C	Invertebrate	.934	.594	.119	.0754
	PLO-06A	Invertebrate	.658	.610	.102	.0945
	PLO-06B	Invertebrate	1.01	.643	.149	.0951
	PLO-06C	Invertebrate	< .620	.620	< .0937	.0937
	PLO-CY01	Invertebrate	.917	.631	.272	.187
Pb	BAR-CY01	Invertebrate	3.27	.292	.886	.0791
	BAR-CY02	Invertebrate	1.48	.274	.454	.0841
	BAR-CY03	Invertebrate	2.08	.284	.666	.0908
	NON-07A	Invertebrate	.510	.288	.0918	.0519
	NON-07B	Invertebrate	< .295	.295	< .0501	.0501
	NON-07C	Invertebrate	< .298	.298	< .0530	.0530
	NON-10A	Invertebrate	7.32	.282	1.16	.0449
	NON-10B	Invertebrate	6.24	.288	.961	.0444
	NON-10C	Invertebrate	7.66	.296	1.17	.0453
	PLO-03A	Invertebrate	.650	.290	.0975	.0435
	PLO-03B	Invertebrate	.530	.286	.0705	.0381
	PLO-03C	Invertebrate	.590	.285	.0749	.0362
	PLO-06A	Invertebrate	.410	.293	.0636	.0454
	PLO-06B	Invertebrate	.390	.308	.0577	.0457
	PLO-06C	Invertebrate	< .298	.298	< .0450	.0450
	PLO-CY01	Invertebrate	.960	.303	.284	.0897
Se	BAR-CY01	Invertebrate	< .608	.608	< .165	.165
	BAR-CY02	Invertebrate	< .571	.571	< .175	.175
	BAR-CY03	Invertebrate	< .591	.591	< .189	.189
	NON-07A	Invertebrate	.910	.601	.164	.108
	NON-07B	Invertebrate	.940	.614	.160	.104
	NON-07C	Invertebrate	1.16	.620	.206	.110
	NON-10A	Invertebrate	1.94	.588	.308	.0935
	NON-10B	Invertebrate	1.98	.601	.305	.0926
	NON-10C	Invertebrate	2.06	.617	.315	.0944
	PLO-03A	Invertebrate	1.11	.604	.166	.0906
	PLO-03B	Invertebrate	1.10	.597	.146	.0794
	PLO-03C	Invertebrate	1.34	.594	.170	.0754
	PLO-06A	Invertebrate	1.18	.610	.183	.0945
	PLO-06B	Invertebrate	1.20	.643	.178	.0951
	PLO-06C	Invertebrate	1.17	.620	.177	.0937
	PLO-CY01	Invertebrate	< .631	.631	< .187	.187
Sr	BAR-CY01	Invertebrate	442.	.243	120.	.0659
	BAR-CY02	Invertebrate	472.	.228	145.	.0701
	BAR-CY03	Invertebrate	487.	.236	156.	.0756
	NON-07A	Invertebrate	100.	.240	18.1	.0433

CONTAMINANT CONCENTRATIONS (Cont.)

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
Sr	NON-07B	Invertebrate	92.4	.246	15.7	.0418
	NON-07C	Invertebrate	76.3	.248	13.6	.0442
	NON-10A	Invertebrate	132.	.235	21.0	.0374
	NON-10B	Invertebrate	118.	.240	18.2	.0370
	NON-10C	Invertebrate	126.	.247	19.3	.0378
	PLO-03A	Invertebrate	169.	.242	25.4	.0362
	PLO-03B	Invertebrate	178.	.239	23.7	.0317
	PLO-03C	Invertebrate	206.	.238	26.2	.0302
	PLO-06A	Invertebrate	79.8	.244	12.4	.0378
	PLO-06B	Invertebrate	104.	.257	15.3	.0381
	PLO-06C	Invertebrate	79.7	.248	12.0	.0375
	PLO-CY01	Invertebrate	530.	.252	157.	.0747
V	BAR-CY01	Invertebrate	< .608	.608	< .165	.165
	BAR-CY02	Invertebrate	< .571	.571	< .175	.175
	BAR-CY03	Invertebrate	< .591	.591	< .189	.189
	NON-07A	Invertebrate	< .601	.601	< .108	.108
	NON-07B	Invertebrate	< .614	.614	< .104	.104
	NON-07C	Invertebrate	< .620	.620	< .110	.110
	NON-10A	Invertebrate	< .588	.588	< .0935	.0935
	NON-10B	Invertebrate	< .601	.601	< .0926	.0926
	NON-10C	Invertebrate	< .617	.617	< .0944	.0944
	PLO-03A	Invertebrate	< .604	.604	< .0906	.0906
	PLO-03B	Invertebrate	< .597	.597	< .0794	.0794
	PLO-03C	Invertebrate	< .594	.594	< .0754	.0754
	PLO-06A	Invertebrate	< .610	.610	< .0945	.0945
	PLO-06B	Invertebrate	< .643	.643	< .0951	.0951
	PLO-06C	Invertebrate	< .620	.620	< .0937	.0937
	PLO-CY01	Invertebrate	< .631	.631	< .187	.187
Zn	BAR-CY01	Invertebrate	128.	1.22	34.7	.330
	BAR-CY02	Invertebrate	83.2	1.14	25.5	.350
	BAR-CY03	Invertebrate	78.1	1.18	25.0	.378
	NON-07A	Invertebrate	118.	1.20	21.2	.216
	NON-07B	Invertebrate	115.	1.23	19.5	.209
	NON-07C	Invertebrate	99.4	1.24	17.7	.221
	NON-10A	Invertebrate	155.	1.18	24.6	.187
	NON-10B	Invertebrate	143.	1.20	22.0	.185
	NON-10C	Invertebrate	147.	1.23	22.5	.189
	PLO-03A	Invertebrate	145.	1.21	21.7	.181
	PLO-03B	Invertebrate	164.	1.19	21.8	.159
	PLO-03C	Invertebrate	140.	1.19	17.8	.151
	PLO-06A	Invertebrate	94.0	1.22	14.6	.189
	PLO-06B	Invertebrate	117.	1.29	17.3	.190
	PLO-06C	Invertebrate	124.	1.24	18.6	.187
	PLO-CY01	Invertebrate	78.7	1.26	23.3	.374

CONTAMINANT CONCENTRATIONS (Cont.)

Analyte	Sample Number	Sample Matrix	Dry Wt. (ppm)	DL Dry (ppm)	Wet Wt. (ppm)	DL Wet (ppm)
methylmercury	BAR-CY01	Invertebrate	.0942	.0200	.0255	.00542
	BAR-CY02	Invertebrate	.0867	.0201	.0266	.00617
	BAR-CY03	Invertebrate	.0804	.0200	.0257	.00640
	NON-07A	Invertebrate	.165	.0199	.0297	.00358
	NON-07B	Invertebrate	.168	.0200	.0286	.00340
	NON-07C	Invertebrate	.168	.0200	.0299	.00356
	NON-10A	Invertebrate	.253	.0200	.0402	.00318
	NON-10B	Invertebrate	.289	.0200	.0445	.00308
	NON-10C	Invertebrate	.290	.0200	.0444	.00306
	PLO-03A	Invertebrate	.176	.0200	.0264	.00300
	PLO-03B	Invertebrate	.141	.0200	.0188	.00266
	PLO-03C	Invertebrate	.0627	.0200	.00796	.00254
	PLO-06A	Invertebrate	.0470	.0200	.00728	.00310
	PLO-06B	Invertebrate	.0790	.0200	.0117	.00296
	PLO-06C	Invertebrate	.0467	.0200	.00705	.00302
	PLO-CY01	Invertebrate	.145	.0200	.0429	.00592

PROCEDURAL BLANKS

Analyte	Lab Sample Number	Lab Sample Matrix	Result Total UG
Al	604161	Animal Tissue	0.000
As	604161	Animal Tissue	0.000
B	604161	Animal Tissue	0.000
Ba	604161	Animal Tissue	.0100
Be	604161	Animal Tissue	0.000
Cd	604161	Animal Tissue	0.000
Cr	604161	Animal Tissue	0.000
Cu	604161	Animal Tissue	.0700
Fe	604161	Animal Tissue	0.000
Hg	604161	Animal Tissue	0.000
Mg	604161	Animal Tissue	.840
Mn	604161	Animal Tissue	0.000
Mo	604161	Animal Tissue	.0600
Ni	604161	Animal Tissue	0.000
Pb	604161	Animal Tissue	0.000
Se	604161	Animal Tissue	0.000
Sr	604161	Animal Tissue	.0200
V	604161	Animal Tissue	0.000
Zn	604161	Animal Tissue	.0200
methylmercury	604166	Animal Tissue	0.000

DUPLICATES

Analyte	Sample Number	Sample Matrix	Wet Dry %	Initial Result (ppm/%)	Duplicate Result (ppm/%)	Average	Relative Percent Diff.
Al	BAR-CY02	Invertebrate	Dry	67.0	61.4	64.2	8.72
	NON-07C	Invertebrate	Dry	< 6.20	< 6.00	3.05	3.42
As	BAR-CY02	Invertebrate	Dry	4.32	4.13	4.22	4.50
	NON-07C	Invertebrate	Dry	6.57	5.99	6.28	9.24
B	BAR-CY02	Invertebrate	Dry	< 2.28	< 2.41	1.17	5.39
	NON-07C	Invertebrate	Dry	< 2.48	< 2.40	1.22	3.41
Ba	BAR-CY02	Invertebrate	Dry	83.4	82.3	82.8	1.27
	NON-07C	Invertebrate	Dry	251.	252.	252.	.720
Be	BAR-CY02	Invertebrate	Dry	< .114	< .120	.0587	5.37
	NON-07C	Invertebrate	Dry	< .124	< .120	.0610	3.44
Cd	BAR-CY02	Invertebrate	Dry	1.00	.990	.997	1.37
	NON-07C	Invertebrate	Dry	1.15	1.13	1.14	1.75
Cr	BAR-CY02	Invertebrate	Dry	2.62	2.52	2.57	3.77
	NON-07C	Invertebrate	Dry	2.96	2.90	2.93	1.81
Cu	BAR-CY02	Invertebrate	Dry	52.1	47.6	49.8	8.99
	NON-07C	Invertebrate	Dry	3.19	3.10	3.14	2.67
Fe	BAR-CY02	Invertebrate	Dry	730.	683.	706.	6.65
	NON-07C	Invertebrate	Dry	3223	3368	3296	4.40
Hg	BAR-CY02	Invertebrate	Dry	.0711	.0694	.0702	2.42
	NON-07C	Invertebrate	Dry	.342	.342	.342	.150
Mg	BAR-CY02	Invertebrate	Dry	1244	1295	1270	4.02
	NON-07C	Invertebrate	Dry	620.	599.	609.	3.45
Mn	BAR-CY02	Invertebrate	Dry	2107	1980	2044	6.21
	NON-07C	Invertebrate	Dry	3264	3282	3273	.550
Mo	BAR-CY02	Invertebrate	Dry	< .571	< .602	.293	5.39
	NON-07C	Invertebrate	Dry	< .620	< .600	.305	3.41
Ni	BAR-CY02	Invertebrate	Dry	2.88	2.74	2.81	5.06
	NON-07C	Invertebrate	Dry	< .620	< .600	.305	3.41
Pb	BAR-CY02	Invertebrate	Dry	1.48	1.56	1.52	5.26
	NON-07C	Invertebrate	Dry	< .298	< .288	.146	3.42

DUPLICATES (Cont.)

Analyte	Sample Number	Sample Matrix	Wet Dry %	Initial Result (ppm/%)	Duplicate Result (ppm/%)	Average	Relative Percent Diff.
Se	BAR-CY02	Invertebrate	Dry	< .571	< .602	.293	5.39
	NON-07C	Invertebrate	Dry	1.16	1.11	1.14	4.41
Sr	BAR-CY02	Invertebrate	Dry	472.	477.	474.	.950
	NON-07C	Invertebrate	Dry	76.3	76.8	76.5	.640
V	BAR-CY02	Invertebrate	Dry	< .571	< .602	.293	5.39
	NON-07C	Invertebrate	Dry	< .620	< .600	.305	3.41
Zn	BAR-CY02	Invertebrate	Dry	83.2	79.4	81.3	4.66
	NON-07C	Invertebrate	Dry	99.4	97.2	98.3	2.23
methylmercury							
	BAR-CY02	Invertebrate	Dry	.0867	.0879	.0873	1.37
	NON-07B	Invertebrate	Dry	.168	.181	.174	7.45

REFERENCE MATERIALS

Analyte	Lab Sample Number	S.R.M. ID	Wet Dry %	Certified Reference Value	95% Confidence Interval	Result (ppm/%)	Percent Recovery
Al	604171	NRCC TORT-2	Dry			< 6.10	
As	604171	NRCC TORT-2	Dry	21.6	1.8	21.4	99.1
B	604171	NRCC TORT-2	Dry			4.07	
Ba	604171	NRCC TORT-2	Dry			1.59	
Be	604171	NRCC TORT-2	Dry			< .122	
Cd	604171	NRCC TORT-2	Dry	26.7	.6	28.7	107.
Cr	604171	NRCC TORT-2	Dry	.77	.15	.774	100.
Cu	604171	NRCC TORT-2	Dry	106	10	96.9	91.4
Fe	604171	NRCC TORT-2	Dry	105	13	93.1	88.7
Hg	604171	NRCC TORT-2	Dry	.27	.06	.230	85.2
Mg	604171	NRCC TORT-2	Dry			1001	
Mn	604171	NRCC TORT-2	Dry	13.6	1.2	13.0	95.6
Mo	604171	NRCC TORT-2	Dry	.95	.1	.658	69.3
Ni	604171	NRCC TORT-2	Dry	2.5	.19	2.24	89.6
Pb	604171	NRCC TORT-2	Dry	.35	.13	.330	94.3
Se	604171	NRCC TORT-2	Dry	5.63	.67	5.47	97.2
Sr	604171	NRCC TORT-2	Dry	45.2	1.9	38.2	84.5
V	604171	NRCC TORT-2	Dry	1.64	.19	1.83	112.
Zn	604171	NRCC TORT-2	Dry	180	6	173.	96.0
methylmercury							
	604186	NRCC DORM-1	Dry			.609	
	604196	NRCC DORM-2	Dry			3.04	

S.R.M. NAMES

S.R.M. ID	S.R.M. Name
NRCC DORM-1	Dogfish Muscle
NRCC DORM-2	Dogfish Muscle
NRCC TORT-2	Lobster Hepatopancreas

SPIKE RECOVERIES

Analyte	Sample Number	Sample Matrix	Wet Dry %	Spike Level (ppm/%)	Amount Recovered (ppm/%)	* Spike / Background	Percent Recovery
Al	BAR-CY01	Invertebrate	Dry	1250	1249	11.3	99.9
	NON-07B	Invertebrate	Dry	1220	1225	200.	100.
As	BAR-CY01	Invertebrate	Dry	6.23	6.65	1.43	107.
	NON-07B	Invertebrate	Dry	6.10	5.33	1.16	87.4
B	BAR-CY01	Invertebrate	Dry	125.	128.	50.1	102.
	NON-07B	Invertebrate	Dry	122.	129.	50.0	106.
Ba	BAR-CY01	Invertebrate	Dry	125.	126.	.900	101.
	NON-07B	Invertebrate	Dry	122.	145.	.440	119.
Be	BAR-CY01	Invertebrate	Dry	125.	127.	1002	101.
	NON-07B	Invertebrate	Dry	122.	127.	1000	104.
Cd	BAR-CY01	Invertebrate	Dry	125.	127.	31.7	102.
	NON-07B	Invertebrate	Dry	122.	131.	82.9	107.
Cr	BAR-CY01	Invertebrate	Dry	125.	128.	28.6	102.
	NON-07B	Invertebrate	Dry	122.	130.	36.0	107.
Cu	BAR-CY01	Invertebrate	Dry	125.	128.	1.33	102.
	NON-07B	Invertebrate	Dry	122.	123.	35.9	100.
Fe	BAR-CY01	Invertebrate	Dry	1250	1276	1.52	102.
	NON-07B	Invertebrate	Dry	1220	1214	.410	99.5
Hg	BAR-CY01	Invertebrate	Dry	1.25	1.16	13.9	93.0
	NON-07B	Invertebrate	Dry	1.22	1.11	3.56	91.2
Mg	BAR-CY01	Invertebrate	Dry	1250	1145	.840	91.6
	NON-07B	Invertebrate	Dry	1220	1357	1.67	111.
Mn	BAR-CY01	Invertebrate	Dry	125.	53.0	.0500	42.4
	NON-07B	Invertebrate	Dry	122.	205.	.0300	168.
Mo	BAR-CY01	Invertebrate	Dry	125.	129.	201.	103.
	NON-07B	Invertebrate	Dry	122.	130.	200.	107.
Ni	BAR-CY01	Invertebrate	Dry	624.	637.	79.2	102.
	NON-07B	Invertebrate	Dry	610.	661.	1000	108.

* For a spike to be a valid measure of method accuracy, this ratio must be higher than 1.0.

SPIKE RECOVERIES (Cont.)

Analyte	Sample Number	Sample Matrix	Wet Dry %	Spike Level (ppm/%)	Amount Recovered (ppm/%)	* Spike / Background	Percent Recovery
Pb	BAR-CY01	Invertebrate	Dry	624.	571.	191.	91.5
	NON-07B	Invertebrate	Dry	610.	563.	2084	92.3
Se	BAR-CY01	Invertebrate	Dry	6.26	6.81	10.0	109.
	NON-07B	Invertebrate	Dry	6.12	5.63	6.51	92.0
Sr	BAR-CY01	Invertebrate	Dry	126.	112.	.290	88.8
	NON-07B	Invertebrate	Dry	123.	129.	1.33	104.
V	BAR-CY01	Invertebrate	Dry	125.	128.	201.	102.
	NON-07B	Invertebrate	Dry	122.	129.	200.	106.
Zn	BAR-CY01	Invertebrate	Dry	125.	122.	.980	98.0
	NON-07B	Invertebrate	Dry	122.	132.	1.06	108.
methylmercury							
	BAR-CY01	Invertebrate	Dry	1.00	.791	10.6	79.1
	NON-07A	Invertebrate	Dry	.996	1.06	6.04	106.

* For a spike to be a valid measure of method accuracy, this ratio must be higher than 1.0.

QA/QC FREQUENCY ANOMALIES

BLANKS: The required number of blanks analyses were performed.

DUPLICATES: The required number of duplicate sample analyses were performed.

SPIKES: The required number of spiked sample analyses were performed.

REFERENCE MATERIALS: The required number of Standard Reference Material analyses were performed.

QA/QC LIMIT OF DETECTION

Limits of Detection were within the contract requirements.

QA/QC ANOMALIES - DUPLICATES

All duplicate results were within normal limits.

QA/QC ANOMALIES - SPIKES

All spiked sample results were within normal limits.

QA/QC ANOMALIES - S.R.M.

All S.R.M. results were within normal limits.

QA/QC COMMENTS

QA/QC and analytical results were approved by: John Moore (PACF).

ANALYTICAL METHODS

This section describes the methods used for analysis by analyte.

Method Codes: 001

Lab Matrix	Analyte(s)
Animal Tissue	% Moisture

METHOD CODE: 001

LABORATORY: Research Triangle Institute

I. Homogenization. Tissue samples are prehomogenized using a food processor. A portion of the tissue sample (or sediment) is then freeze dried for determination of moisture content and ground to 100 mesh with a mill.

ANALYTICAL METHODS

This section describes the methods used for analysis by analyte.

Method Codes: 001 004 006

Lab Matrix	Analyte(s)
Animal Tissue	Al
	B
	Ba
	Be
	Cd
	Cr
	Cu
	Fe
	Mg
	Mn
	Mo
	Ni
	Sr
	V
	Zn

METHOD CODE: 001

LABORATORY: Research Triangle Institute

I. Homogenization. Tissue samples are prehomogenized using a food processor. A portion of the tissue sample (or sediment) is then freeze dried for determination of moisture content and ground to 100 mesh with a mill.

METHOD CODE: 004

LABORATORY: Research Triangle Institute

IV. Digestion for Graphite Furnace and Cold Vapor Atomic Absorption (GFAA) Measurement. Using a CEM microwave oven, 0.25 to 0.5 g of freeze dried sample is heated in a capped 120 ml Teflon vessel in the presence of 5 ml of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and fifteen minutes at 450 watts. The residue is then diluted to 50 ml with laboratory pure water.

ANALYTICAL METHODS (Cont.)

METHOD CODE: 006

LABORATORY: Research Triangle Institute

VI. ICP. ICP measurements are made using a Leeman Labs Plasma Spec I sequential or ES2000 simultaneous spectrometer.

ANALYTICAL METHODS

This section describes the methods used for analysis by analyte.

Method Codes: 001 004 007

Lab Matrix	Analyte(s)
Animal Tissue	As
	Pb
	Se

METHOD CODE: 001

LABORATORY: Research Triangle Institute

I. Homogenization. Tissue samples are prehomogenized using a food processor. A portion of the tissue sample (or sediment) is then freeze dried for determination of moisture content and ground to 100 mesh with a mill.

METHOD CODE: 004

LABORATORY: Research Triangle Institute

IV. Digestion for Graphite Furnace and Cold Vapor Atomic Absorption (GFAA) Measurement. Using a CEM microwave oven, 0.25 to 0.5 g of freeze dried sample is heated in a capped 120 ml Teflon vessel in the presence of 5 ml of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and fifteen minutes at 450 watts. The residue is then diluted to 50 ml with laboratory pure water.

METHOD CODE: 007

LABORATORY: Research Triangle Institute

VII. Graphite Furnace Atomic Absorption (GFAA). GFAA measurements are made using a Perkin-Elmer Zeeman 3030 or 4100ZL atomic absorption spectrometer.

ANALYTICAL METHODS

This section describes the methods used for analysis by analyte.

Method Codes: 001 004 008

Lab Matrix	Analyte(s)
Animal Tissue	Hg

METHOD CODE: 001

LABORATORY: Research Triangle Institute

I. Homogenization. Tissue samples are prehomogenized using a food processor. A portion of the tissue sample (or sediment) is then freeze dried for determination of moisture content and ground to 100 mesh with a mill.

METHOD CODE: 004

LABORATORY: Research Triangle Institute

IV. Digestion for Graphite Furnace and Cold Vapor Atomic Absorption (GFAA) Measurement. Using a CEM microwave oven, 0.25 to 0.5 g of freeze dried sample is heated in a capped 120 ml Teflon vessel in the presence of 5 ml of Baker Instra-Analyzed nitric acid for three minutes at 120 watts, three minutes at 300 watts, and fifteen minutes at 450 watts. The residue is then diluted to 50 ml with laboratory pure water.

METHOD CODE: 008

LABORATORY: Research Triangle Institute

VIII. Cold Vapor Atomic Absorption (CVAA). Hg measurements are conducted using SnC14 as the reducing agent. A Leeman PS200 Hg Analyzer is employed.

ANALYTICAL METHODS

This section describes the methods used for analysis by analyte.

Method Codes: 001 048 008

Lab Matrix	Analyte(s)
Animal Tissue	methylmercury

METHOD CODE: 001

LABORATORY: Research Triangle Institute

I. Homogenization. Tissue samples are prehomogenized using a food processor. A portion of the tissue sample (or sediment) is then freeze dried for determination of moisture content and ground to 100 mesh with a mill.

METHOD CODE: 008

LABORATORY: Research Triangle Institute

VIII. Cold Vapor Atomic Absorption (CVAA). Hg measurements are conducted using SnC14 as the reducing agent. A Leeman PS200 Hg Analyzer is employed.

METHOD CODE: 048

LABORATORY: Research Triangle Institute

Methylmercury

XLVIII. Extraction of methylmercury. The sample was treated with 10 ml of 5 mol/l HCI to liberate methylmercury (plus any other organomercury species), which was then extracted into 3 x 20 ml aliquots of toluene. The combined toluene aliquots was diluted to 100 ml with toluene. This solution was amenable to gas chromatography. For the other techniques which accept only aqueous samples, methylmercury was extracted from the toluene solution with a cysteine acetate solution, 4/1 v/v. To prepare the cysteine acetate solution, 0.5 g of cysteine hydrochloride monohydrate, 0.34 g of sodium acetate and 6.25 g of anhydrous sodium sulphate was dissolved in 50 ml of DDW.

Cold vapor atomic absorption spectrometry. Digestion: EPA method 7470 (nitric, sulfuric acids permangante, persulfate). After

ANALYTICAL METHODS (Cont.)

digestion the resulting solution was then subjected to CVAAS. An automated mercury analyzer, the Leeman Labs PS200, was used for measurement. The reducing agent was a solution of stannous chloride and hydroxylamine hydrochloride (2/1).

Reference:

Marine Biological Reference Materials for Methylmercury: Analytical Methodologies Used in Certification. Fresenius Z Anal. Chem. (1989) 333:641-644.